

# TABLE OF CONTENTS

## Subject Categories

*Abstracts in this bibliography are grouped under the following categories*

*page*

### 01 SYSTEMS

Includes mission requirements, focus missions, conceptual studies, technology planning, and systems integration.

1 1/A12

### 02 INTERACTIVE ANALYSIS AND DESIGN

Includes computerized technology design and development programs, dynamic analysis techniques, thermal modeling, and math modeling.

7 1/B4

### 03 STRUCTURAL CONCEPTS

Includes erectable structures (joints, struts, and columns), deployable platforms and booms, solar sail, deployable reflectors, space fabrication techniques and protrusion processing.

9 1/B6

### 04 CONTROL SYSTEMS

Includes new attitude and control techniques, improved surface accuracy measurement and control techniques.

13 1/B10

### 05 ELECTRONICS

Includes techniques for power and data distribution.

21 1/C4

### 06 ADVANCED MATERIALS

Includes matrix composites, polyimide films and thermal control coatings, and space environmental effects on these materials.

23 1/C6

### 07 ASSEMBLY CONCEPTS

Includes automated manipulator techniques, EVA, robot assembly, teleoperators, and equipment installation.

27 1/C10

### 08 PROPULSION

Includes propulsion designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts.

29 1/C12

### 09 FLIGHT EXPERIMENTS

Includes controlled experiments requiring high vacuum and zero G environment.

33 1/D2

### 10 SOLAR POWER SATELLITE SYSTEM

Includes solar power satellite concepts with emphasis upon structures, materials, and controls.

35 1/D4

### 11 GENERAL

Includes either state-of-the-art or advanced technology which may apply to Large Space Systems and does not fit within the previous nine categories. Shuttle payload requirements, on-board requirements, data rates, and shuttle interfaces, and publications of conferences, seminars, and workshops will be covered in this area.

47 1/E2

SUBJECT INDEX .....	A 1 1/E7
PERSONAL AUTHOR INDEX .....	B 1 1/G9
CORPORATE SOURCE INDEX .....	C 1 2/A5
CONTRACT NUMBER INDEX .....	D 1 2/A10
REPORT/ACCESSION NUMBER INDEX .....	F 1 2/A11

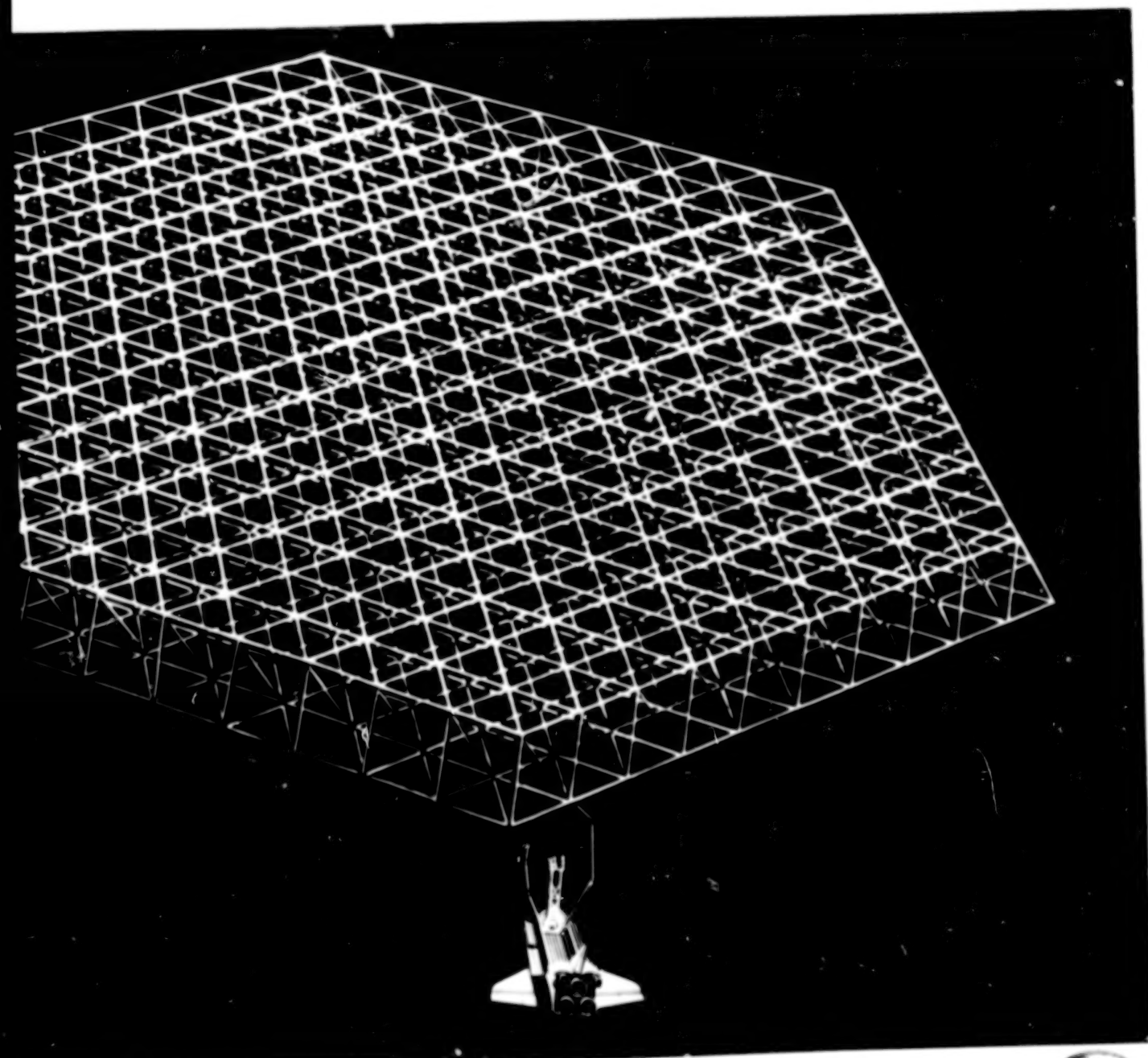
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Technology for  
Large Space Systems  
A Special  
Bibliography  
with Indexes

NSI-21:7046(02)  
NASA SP-7046(02)  
January 1981

COMPLETED  
ORIGINAL

National Aeronautics and  
Space Administration



# TECHNOLOGY FOR LARGE SPACE SYSTEMS

**A Special Bibliography  
With Indexes**

**Supplement 2**

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced between July 1, 1979 and December 31, 1979.

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA)*

This Supplement is available from the National Technical Information Service (NTIS),  
Springfield, Virginia 22161, at the price code A06 (\$9.00 domestic; \$18.00 foreign).



# INTRODUCTION

This special bibliography is designed to be helpful to the researcher and manager engaged in developing technology within the discipline areas of the Large Space Systems Technology (LSST) Program. Also, the designers of large space systems for approved missions (in the future) will utilize the technology described in the documents referenced herein.

This literature survey lists 258 reports, articles and other documents announced between July 1, 1979 and December 31, 1979 in *Scientific and Technical Aerospace Reports (STAR)* and *International Aerospace Abstracts (IAA)*.

The coverage includes documents that define specific missions that will require large space structures to achieve their objectives. The methods of integrating advanced technology into system configurations and ascertaining the resulting capabilities is also addressed.

A wide range of structural concepts are identified. These include erectable structures which are earth fabricated and space assembled, deployable platforms and deployable antennas which are fabricated, assembled, and packaged on Earth with automatic deployment in space, and space fabricated structures which use pre-processed materials to build the structure in orbit.

The supportive technology that is necessary for full utilization of these concepts is also included. These technologies are identified as Interactive Analysis and Design, Control Systems, Electronics, Advanced Materials, Assembly Concepts, and Propulsion. Electronics is a very limited field in this bibliography, primarily addressing power and data distribution techniques.

This issue of the bibliography will also contain citations to documents dealing primarily with the Solar Power Satellite System (SPS) as will subsequent issues.

The reader will not find references to material that has been designated as "limited" distribution or security classified material. These types of documents will be identified by the LSST Program Office, and a separate listing will be distributed to selected recipients.

A Flight Experiments category and a General category complete the list of subjects addressed by this document.

The selected items are grouped into eleven categories as listed in the Table of Contents with notes regarding the scope of each category. These categories were especially selected for this publication and differ from those normally found in *STAR* and *IAA*.

Each entry consists of a standard bibliographic citation accompanied by an abstract where available. The citations and abstracts are reproduced exactly as they appeared originally in *STAR* and *IAA* including the original accession numbers from the respective announcement journals. This procedure accounts for the variation in citation appearance.

Under each of the eleven categories, the entries are presented in one of two groups that appear in the following order:

- 1) *IAA* entries identified by accession number series A79-10,000 in ascending accession number order;
- 2) *STAR* entries identified by accession number series N79-10,000 in ascending accession number order.

After the abstract section there are five indexes - subject, personal author, corporate source, contract number, and report/accession number

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All publications abstracted in this Section are available from the Technical Information Service, American Institute of Aeronautics and Astronautics, Inc. (AIAA), as follows: Paper copies of accessions are available at \$6.00 per document up to a maximum of 20 pages. The charge for each additional page is \$0.25. Microfiche<sup>(1)</sup> of documents announced in IAA are available at the rate of \$2.50 per microfiche on demand, and at the rate of \$1.10 per microfiche for standing orders for all IAA microfiche. The price for the IAA microfiche by category is available at the rate of \$1.25 per microfiche plus a \$1.00 service charge per category per issue. Microfiche of all the current AIAA Meeting Papers are available on a standing order basis at the rate of \$1.35 per microfiche.

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# TABLE OF CONTENTS

## Subject Categories

*Abstracts in this bibliography are grouped under the following categories*

*page*

### 01 SYSTEMS

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1

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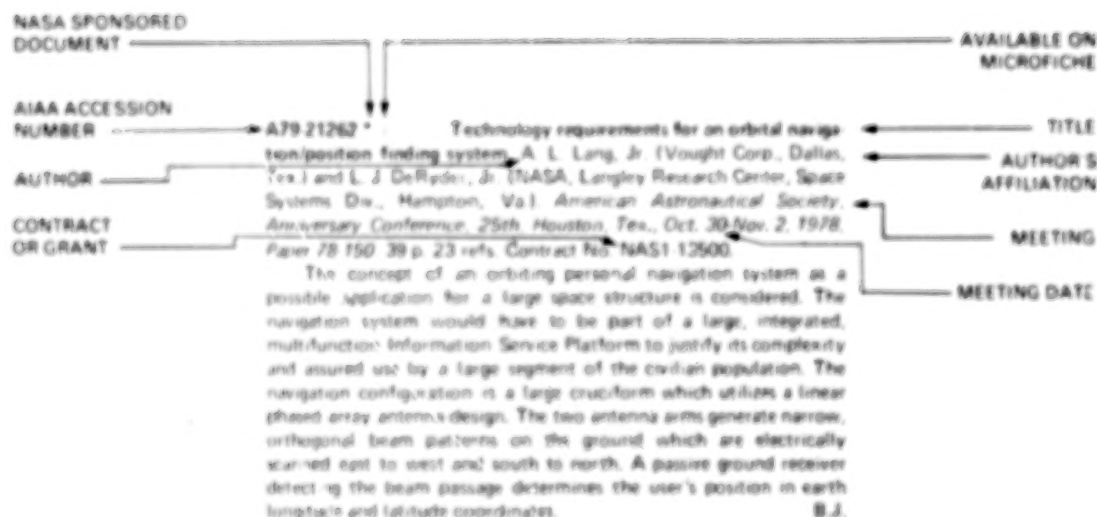
47

<b>SUBJECT INDEX</b> .....	<b>A-1</b>
<b>PERSONAL AUTHOR INDEX</b> .....	<b>B-1</b>
<b>CORPORATE SOURCE INDEX</b> .....	<b>C-1</b>
<b>CONTRACT NUMBER INDEX</b> .....	<b>D-1</b>
<b>REPORT/ACCESSION NUMBER INDEX</b> .....	<b>E-1</b>

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# TECHNOLOGY FOR LARGE SPACE SYSTEMS

*A Special Bibliography (Suppl. 2)*

JANUARY 1980

## 01 SYSTEMS

**Includes mission requirements, focus missions, conceptual studies, technology planning, and systems integration.**

**A79-34702 \* p** Design and operations technologies - Integrating the pieces. C. H. Eldred (NASA, Langley Research Center, Advanced Technology Group, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 5-11, 14 refs. (AIAA 79-0858)

As major elements of life-cycle costs (LCC) having critical impacts on the initiation and utilization of future space programs, the areas of vehicle design and operations are reviewed in order to identify technology requirements. Common to both areas is the requirement for efficient integration of broad, complex systems. Operations technologies focus on the extension of space-based capabilities and cost reduction through the combination of innovative design, low-maintenance hardware, and increased manpower productivity. Design technologies focus on computer-aided techniques which increase productivity while maintaining a high degree of flexibility which enhances creativity and permits graceful design change. (Author)

**A79-34742 \* p** A technology program for large area space systems. A. Guastafiero (NASA, Langley Research Center, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 343-353. (AIAA 79-0921)

The broad objective of the Large Space Systems Technology (LSST) program is to define and develop the necessary technology for large space systems and associated subsystems required for projected NASA space missions. It is a goal of LSST to make these systems economically and technically feasible by focusing on those technical activities believed to provide the greatest benefit to a variety of future systems. Emphasis is placed on two principal structural configurations: antennae and platforms. B.J.

**A79-34761 \* p** Global services systems - Space communication. F. H. Sheppard and H. L. Wolfers (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 519-525, 10 refs. Contract No. NAS7-12346. NASA Task 28. (AIAA 79-0946)

The requirements projected to the year 2000 for space-based global service systems, including both personal communications and innovative services, are developed based on historic trends and anticipated worldwide demographic and economic growth patterns. The growing demands appear to be best satisfied by developing larger, more sophisticated space systems in order to reduce the size,

complexity, and expense of ground terminals. The availability of low-cost ground terminals will, in turn, further stimulate the generation of new services and new customers. B.J.

**A79-34762 \* p** Space-based radio telescopes and an orbiting deep-space relay station. R. V. Powell (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 526-534, 19 refs. Contract No. NAS7-100. (AIAA 79-0947)

Foremost among the candidates for early utilization of the Shuttle-launched self-deployable structures are the space-based radio telescopes. Several space-based telescopes are examined including an orbiting VLBI terminal, an orbiting submillimeter telescope, and a large ambient deployable IR telescope. Particular consideration is given to the high-gain Orbiting Deep-Space Relay Station for communication with deep-space probes. Details of deployable antenna technology are discussed. B.J.

**A79-34868** Technical challenges of large space systems in the 21st century. J. J. Kirby (Grumman Aerospace Corp., Bethpage, N.Y.). In: The future United States space program, Proceedings of the Twenty-fifth Anniversary Conference, Houston, Tex., October 30-November 2, 1978, Part 2. San Diego, Calif., American Astronautical Society, Univelt, Inc., 1979, p. 791-815. (AAS 78-195)

Exciting prospects exist in both the exploration and exploitation of space. Mission requirements are discussed relative to space science, space applications, and engineering support. Technical concepts and examples are considered in relation to structures, propulsion, stabilization and control, human factors, electronics, space manufacturing, and heat rejection systems. Implications for today are discussed with respect to need for supporting technology, dominance of economic considerations, and educational concerns for engineers. S.O.

**A79-36549 p** Space structure - A key to new opportunities. R. L. Kline (Grumman Aerospace Corp., Bethpage, N.Y.). American Astronautical Society, Gordon Memorial Symposium, Washington, D.C., Mar. 28-30, 1979, Paper 79-059, 15 p., 10 refs.

Applications of two future space structure techniques, Deployable Antennas and Space Construction/Satellite Servicing, and the means of achieving their practical usage are outlined. These space structures will be possible due to the Space Shuttle capability of delivering large, heavy payloads (up to 65,000 lb) into space with crews of space workers. Space structures provided by Construction Missions 1 to 5 are presented, and potential deployable antenna applications including multibeam communication repeater, electronic mail delivery, radar tracking of ground and airborne targets, and earth-looking radiometer are described. Space Construction/Servicing applications will range from development of the solar power satellite technology to space platform operations and satellite servicing. Space fabrication equipment is described, and the Manned Remote Work Station is discussed as an example of future satellite repair activities. It is concluded that space experimental demonstrations should be made to show prospective users that they can include the large deployable antenna and space fabrication/satellite servicing features in their future planning. A.T.



## 01 SYSTEMS

**A79-45423 \*** **A Microwave Radiometer Spacecraft, some control requirements and concepts.** U. M. Lovelace (NASA, Langley Research Center, Hampton, Va.), In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers, New York, American Institute of Aeronautics and Astronautics, Inc., 1979, 8 p. (AIAA 79-1777)

A general overview of a conceptual design for a Microwave Radiometer Spacecraft using a large passive reflector, microwave radiometers, and advanced control concepts is presented. The mission requirements, developed around high resolution, large area mapping of soil moisture for global crop forecasting, are reviewed. These mission requirements, along with system design requirements, dictate the need for a reflector in excess of 700 meters in diameter. Conceptual designs for supporting structures and subsystems, including attitude and surface control, are summarized. (Author)

**A79-50459** **The possibilities of SETI from space.** R. P. Bader (SRI International, Menlo Park, Calif.), *Cosmic Search*, vol. 1, Fall 1979, p. 41-45.

Radio systems to be used in the search for extraterrestrial intelligence (SETI) are discussed. Parameters involved in the choice of such a system are presented, and possible configurations for earth-based and orbiting systems and systems of radio antennas located on the far side of the moon are compared on the basis of cost, practicality and technical factors. An incremental SETI program based on the cumulative development and implementation of earth-based, then space-based radio telescopes is suggested, which would allow the completion of a search for extraterrestrial radio beacons in the 18 to 21-cm range by the second decade of the next century. Finally, motivations for the transmission of and search for extraterrestrial messages are discussed, and implications of the results of such a search for the future of advanced technological civilization are noted. A.L.W.

**A79-51149** **Satellite clusters.** P. S. Visser (Hughes Aircraft Co., Aircraft Space and Communications Group, Culver City, Calif.), *Satellite Communications*, Sept. 1979, p. 22-24, 27.

Satellite clusters are proposed as an alternative to sophisticated space platforms to provide increased communications capacity at lower cost. Advantages discussed include simpler implementation, multiple reuse of frequencies, the capability to replace a single module if it fails, and indifference to a mixture of technologies. Attention is also given to the fact that less earth stations would be needed since each would have a greater capacity. Another benefit cited is that a 50 or 60 foot L-Band antenna could be introduced to greatly reduce the cost of ship-borne terminals, as well as search and rescue services. It is concluded that cluster capability could be implemented in four or five years. M.E.P.

**A79-51892** **Orbital antenna farm power system challenges.** F. H. Esch and W. L. Morgan (COMSAT Laboratories, Clarksburg, Md.), In: Intersociety Energy Conversion Engineering Conference, 14th, Boston, Mass., August 5-10, 1978, Proceedings, Volume 2, Washington, D.C., American Chemical Society, 1979, p. 1207-1212. Research sponsored by the Communications Satellite Corp.

This paper describes possible orbital antenna farm (OAF) systems and identifies power system design problems which must be solved. The OAF is a space platform which combines a variety of communication services on a common platform and provides varying amounts of electric power depending on amounts of communications service. Long life and high reliability are economic justifications for OAF, so that an OAF platform is expected to operate for several decades. The platform capabilities of the several initial space stations of the OAF class and applications missions of the earliest OAF designs in the geostationary orbit are summarized. The platform power distribution among these missions, space station construction, and interconnected platforms for global traffic are discussed. The

OAF electric power system, including nuclear and photovoltaic generators, and energy storage systems, such as thermoelectric conversion and rotating-inertia devices are described. A.T.

**A79-52674 \*** **NASA technology for large space antennas.** R. A. Russell, T. G. Campbell (NASA, Langley Research Center, Hampton, Va.), and R. E. Freedland (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.), In: AGARD, Structures and Materials Panel Meeting, 49th, Porz-Wahn, West Germany, Oct. 7-12, 1979, Paper 32 p. 14 refs.

Technology developed by NASA in conjunction with industry for potential large, deployable space antennas with applications in communication, radio astronomy and earth observation is reviewed. Concepts for deployable antennas that have been developed to the point of detail design are summarized, including the advanced sunflower precision antenna, the spiral rib antenna, the maypole (hoop/column) antenna and the parabolic inflatable truss antenna. The assessment of state-of-the-art deployable antenna technology is discussed, and the approach taken by the NASA Large Space Systems Technology (LSST) Program to the development of technology for large space antenna systems is outlined. Finally, the further development of the spiral rib antenna and the maypole (hoop/column) concept, which meet mission model requirements, to satisfy LSST size and frequency requirements is discussed. A.L.W.

**A79-53300 \*** **A technology base for near-term space platforms.** E. K. Hocking, III (NASA, Office of Aeronautics and Space Technology, Washington, D.C.) and A. Guarafiero (NASA, Langley Research Center, Hampton, Va.), *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-110*, 20 p. 18 refs.

The paper briefly describes the ongoing Large Space Systems Technology (LSST) Program in platform technology. The program addresses technology issues associated with the near-term science and applications platform, and the more fundamental questions associated with the general class of large space-assembled structural systems. Elements of the technology program are described and preliminary results are discussed. Results to date indicate that potential new capabilities of the Space Shuttle will strongly influence spacecraft design, and that future spacecraft utilizing these new capabilities can provide important new performance capabilities and greater efficiency. The proposed science and applications platform appears to be the earliest envisioned space vehicle which will be of the space-assembled class. S.D.

**A79-53357 \*** **Orbital demonstration - The prelude to large operational structures in space.** T. Hajer (NASA, Office of Advanced Programs, Washington, D.C.), *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-207*, 16 p. Contracts No. NAS9-15310, No. NAS9-32394, No. NAS9-14916.

The paper surveys three specific large space structures which have been analyzed to determine the technology needed to achieve a fully operational system. They are the multipurpose platforms, satellite power systems, and a deployable antenna. Further attention is also given to these technology needs which can be satisfied by ground based technology (simulation), such as payload carrier modification or design, platform element connectors and fittings, data compression and storage equipment, man-machine interface and productivity assessment, and astronaut aids. Also covered are those technology and performance parameters which require demonstration in orbit. M.E.P.

**A79-53358 \*** **New space initiative through large generic structures.** R. W. Johnson (NASA, Washington, D.C.; Grumman Aerospace Corp., Bethpage, N.Y.), *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-208*, 16 p. Contracts No. NAS9-15310, No. NAS9-32394, No. NAS9-14916.

ation, *International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-208, 36 p, 6 refs.*

New possibilities in satellite communications, surveillance, and orbital escape, mentioned provided by the capability to construct and deploy Large Space Structures (LSS) are presented. The advent of the Shuttle will allow deployment of large antennas with much larger gain sizes, noting new applications in communications, radiometry, and radar in frequencies from 0.24 to 14 GHz. Application, in multi-beam communication which can hold spot sizes on the ground down to 30 miles in diameter, new applications of the large aperture radar antenna, and estimates of soil moisture by the microwave radiometer are discussed. The Solar Power Satellite consisting of a large solar collector orbiting the earth at geosynchronous altitude over the equator which requires ability to construct LSS in space is described, noting the design of solar cells and materials of construction, including graphite composites and aluminum alloys. Space construction procedures and equipment are considered, noting that the most likely procedure would deliver the subsystems to orbit separately, and then construct the spacecraft on-orbit and assemble the satellite. A.T.

**A79-53405** Multi-cell satellite for the communications of year 2000. E. Golden and J. Dilly (Nutra, S.A., Paris, France). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-301, 14 p.*

An efficient, large communications satellite concept for the year 2000 is presented. Attention is given to the payload description, satellite assembly process, and transfer into geostationary orbit. Also discussed are the major characteristics of a typical multi-cell satellite including typical mission, system and satellite main characteristics, and assembly and launching. It is concluded that the total traffic of 100 Gb/s represents the equivalent of 2,125,000 telephony channels (32 kb/s delta modulation), 100 or 150 times more than the traffic of the largest satellite launched in the next 2 or 3 years. R.E.P.

**A79-53406** The critical satellite technical issues of future pervasive broadband low-cost communication networks. R. L. Harvey (MIT, Lincoln Laboratory, Lexington, Mass.) *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-302, 21 p, 28 refs, Contract No. NAS-75091.*

The critical technical issues of signal waveform design, projected spacecraft technology, satellite launch options, and satellite cost are discussed for future pervasive broadband communication networks. With DPCM video signal encoding, 32 Mb/s user-to-user data rate per channel, 10% overhead, two orthogonal polarizations, and crosstalk loss limited to 1 dB, TFM permits about 75 channels/GHz of frequency allocation. The BOM (beginning of mission) weight and power of a baseline 400-channel multibeam satellite is about 1800 kg and 5000 W. Each 35 Mb/s channel can support 1 to 10 video channels. The weight and power estimates assume hardened digital logic, composite materials for a multibeam antenna structure, high-efficiency solar cells, batteries, and amplifiers. Based on a cost model for large communication satellites, the total space segment cost of two active satellites and one spare would be about \$485 M. V.T.

**A79-53409** Trends in the design of future communications satellite systems. H. Harthorn (Telefunken AG, Bad Nauheim, West Germany), P. Hartl (Berlin, Technische Universität, Berlin, West Germany), and H. Treitz (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Cologne, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-307, 34 p, 12 refs.*

The present discussion indicates that the trends in the design of satellite communications in the immediate future point to a considerable increase in the number of satellites of moderate size, optimized to satisfy imminent communications needs. In industrialized countries, present demand is primarily for digital data transfer, computer interconnection, and business communications. In developing countries, emphasis will be on national and regional telephony networks designed to improve the basic communication infrastructure. In the long-term international coordination of orbit and spectrum allocations, introduction of (spectrum-conserving) higher frequency bands and large communication platforms is to be expected. Some current contributions to these developments are noted, particularly with respect to high-power TWTs in the 12 to 20 cm range. V.P.

**A79-53433** Employment of large structure communications satellites for emergency calls. G. Lenzauer and E. Messerschmid (deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Institut für Nachrichtentechnik, Oberpfaffenhofen, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-A-34, 14 p, 21 refs.*

The application of large antenna structures for communication satellites reduces the transmitter equipment of distress and emergency call systems. The transmitter weight is minimum for emergency transmission around L-band frequencies. For simple emergency messages (100 bps) and speech transmissions (10,000 bps) and antenna diameters larger than few meters, transmitters can be made portable. Large space antennas together with such techniques as electronically switched multibeam antennas and efficient multiple access systems make it possible the frequency reuse based on quaternary concept. V.T.

**N79-22125\*** National Aeronautics and Space Administration, Washington, D. C. [SOME ACTIVITIES AND VEHICLE CONCEPTS ENVISIONED FOR FUTURE EARTH ORBITAL MISSIONS] Bobby G. Noblet. In: Von Kármán Inst. for Fluid Dyn. Technol. of Space Shuttle Vehicles, Vol. 1, 1979, 24 p.

Avail. NTIS HC A25/MF A01 CSCL 228

Mission requirements, payloads and vehicles are discussed with regard to their mutual interaction. G.V.

**N79-22174\*** National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Md. SYNCHRONOUS ORBIT POWER TECHNOLOGY NEEDS Luther W. Sider, Jr. and W. J. Siderbeck (COMSAT Labs., Clarksburg, Md.) Apr. 1979, 36 p, refs. (NASA-TM-80280) Avail. NTIS HC A03/MF A01 CSCL 22A

The needs are defined for future geosynchronous orbit spacecraft power subsystem components, including power generation, energy storage, and power processing. A review of the rapid expansion of the satellite communications field provides a basis for projection into the future. Three projected models, a mission model, an orbit transfer vehicle model, and a mass model for power subsystem components are used to define power requirements and mass limitations for future spacecraft. Based upon these three models, the power subsystems for a 10 kw, 10 year life, dedicated spacecraft and for a 20 kw, 20 year life, multi-mission platform are analyzed in further detail to establish power density requirements for the generation, storage and processing components of power subsystems as related to orbit transfer vehicle capabilities. Comparison of these requirements to state of the art design values shows that major improvements, by a factor of 2 or more, are needed to accomplish the near term missions. However, with the advent of large transfer vehicles, these requirements are significantly reduced, leaving the long lifetime requirement, associated with reliability and/or

## 01 SYSTEMS

refurbishment, as the primary development need. A few technology advances, currently under development, are noted with regard to their impacts on future capability. L S

**N79-22191\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### RESULTS FROM SYMPOSIUM ON FUTURE ORBITAL POWER SYSTEMS TECHNOLOGY REQUIREMENTS

Sol Gorland 1979 8 p refs To be presented at the 14th Intersoc. Energy Conversion Eng. Conf., Boston, 5-10 Aug 1979, sponsored by the Am. Chem. Soc.

(NASA-TM-79125; E-9961) Avail NTIS HC A02/MF A01 CSCL 10B

The technology requirements for future orbital power systems were reviewed. Workshops were held in 10 technology disciplines to discuss technology deficiencies, adequacy of current programs to resolve those deficiencies and recommendations for tasks that might reduce the testing and risks involved in future orbital energy systems. Those recommendations are summarized J M S

**N79-23126\*** General Electric Co., Philadelphia, Pa. Space Div.

### MISSION SPECIFICATION FOR THREE GENERIC MISSION CLASSES Final Report

May 1979 154 p refs

(Contract NAS1-15642)

(NASA-CR-159048) Avail NTIS HC A08/MF A01 CSCL 22A

Mission specifications for three generic mission classes are generated to provide a baseline for definition and analysis of data acquisition platform system concepts. The mission specifications define compatible groupings of sensors that satisfy specific earth resources and environmental mission objectives. The driving force behind the definition of sensor groupings is mission need; platform and space transportation system constraints are of secondary importance. The three generic mission classes are: (1) low earth orbit sun-synchronous; (2) geosynchronous; and (3) non-sun-synchronous, nongeosynchronous. These missions are chosen to provide a variety of sensor complements and implementation concepts. Each mission specification relates mission categories, mission objectives, measured parameters, and candidate sensors to orbits and coverage, operations compatibility, and platform fleet size. Author

**N79-27378\*** Thomson-CSF, Meudon-la-Foret (France) Dept. Espace-Satellites

### FEASIBILITY STUDY FOR A SATELLITE FREQUENCY MODULATED RADIO COMMUNICATION SYSTEM Final Report [ETUDE DE FAISABILITE D'UN SYSTEME DE RADIO-DIFFUSION SONORE A MODULATION DE FREQUENCE PAR SATELLITE, VOLUME I]

V. Biggs, B. Vidal-Saint Andrie, P. MacNamara (Telecommun. Ltd), and F. Horgan (Telecommun. Ltd) Oct 1978 148 p Partly in French and English 2 Vol

(Contract ESA-3208/77-F-HGE(SC))

(ESA-CRIP-1151-Vol-1) Avail NTIS HC A07/MF A01

The final report on the feasibility study for a satellite frequency modulated radio communication system is presented. The main subjects covered are the ground link (antenna gain, attenuation effects, multipath problems, etc.), the space link (power stage, multiplexing, large orbital antennas), and the parametric study of space to ground communication (industrial noise, wave polarization, optimal frequency, transmitting power, etc.). The system is reported feasible for national communication purposes and is more economic for low latitude countries than others. The choice of the 1 GHz frequency for the space to ground link is confirmed. Author (ESA)

**N79-30266\*** Rockwell International Corp., Downey, Calif. Satellite Systems Div.

### SPACE CONSTRUCTION SYSTEM ANALYSIS. PART 1: EXECUTIVE SUMMARY Final Report

Jun 1979 295 p

(Contract NAS9-15718)

(NASA-CR-160295; SSD-79-0123)

Avail NTIS

HC A13/MF A01 CSCL 22A

System analysis studies of space construction projects, primarily dealing with areas of space construction support services, construction facilities, orbit altitude, and orbit transfer are presented. R E S.

**N79-30268\*** Rockwell International Corp., Downey, Calif. Satellite Systems Div.

### SPACE CONSTRUCTION DATA BASE

Jun 1979 430 p refs

(Contract NAS9-15718)

(NASA-CR-160297; SSD-79-0125)

Avail NTIS

HC A19/MF A01 CSCL 22A

Construction of large systems in space is a technology requiring the development of construction methods to deploy, assemble, and fabricate the elements comprising such systems. A construction method is comprised of all essential functions and operations and related support equipment necessary to accomplish a specific construction task in a particular way. The data base objective is to provide to the designers of large space systems a compendium of the various space construction methods which could have application to their projects. G Y.

**N79-30269\*** Rockwell International Corp., Downey, Calif. Space Div.

### SPACE CONSTRUCTION SYSTEM ANALYSIS. PART 1: EXECUTIVE SUMMARY. SPECIAL EMPHASIS STUDIES Final Report

Jun 1979 186 p ref

(Contract NAS9-15718)

(NASA-CR-160298; SSD-79-0126)

Avail NTIS

HC A09/MF A01 CSCL 22A

Generic concepts were analyzed to determine: (1) the maximum size of a deployable solar array which might be packaged into a single orbit payload bay; (2) the optimal overall shape of a large erectable structure for large satellite projects; (3) the optimization of electronic communication with emphasis on the number of antennas and their diameters; and (4) the number of beams, traffic growth, and projections and frequencies were found feasible to package a deployable solar array which could generate over 250 kilowatts of electrical power. Also, it was found that the linear-shaped erectable structure is better for ease of construction and installation of systems, and compares favorably on several other counts. The study of electronic communication technology indicated that proliferation of individual satellites will crowd the spectrum by the early 1990's, so that there will be a strong tendency toward a small number of communications platforms over the continental U.S.A. with many antennas and multiple spot beams. A R H.

**N79-30748\*** British Aerospace Dynamics Group, Bristol (England).

### A STUDY ON SOLAR ARRAYS FOR PROGRAMMES LEADING FROM THE EXTENSION OF SPACELAB TOWARDS SPACE PLATFORMS

P R C Gillett In ESA Photovoltaic Generators in Space Nov. 1978 p 119-129 refs Sponsored by ESA

Avail NTIS HC A15/MF A01

A review of a mission scenario covering the period from 1982 to the end of the century is presented, including some

## 01 SYSTEMS

preliminary solar array concepts. These concepts range from the augmentation of Spacelab by 6 kW arrays through Power Module and Space Platform arrays along with Pilot Power Plants, to a brief examination of 10 GW Space Solar Power Stations. The second phase of the study concentrates on concepts for a 50 kW Orbiter mounted array, a 55 kW Power Module array, and two types of 2.50 kW Space Platform arrays, these representing items of likely interest for European contributions to the near and medium term programs. Finally, an outline strategy for the implementation of these arrays is considered. Author (ESA)

**N79-30879\*** National Aeronautics and Space Administration  
Marshall Space Flight Center, Huntsville, Ala

### **PLATFORMS IN SPACE: EVOLUTIONARY TRENDS**

John M. Butler, Jr. In its Proc. Workshop on the Need for  
Lightning Observations from Space Jul 1979 p 159-182

Avail: NTIS HC A12/MF A01 CSCL 22A

The problem of physical crowding and the proliferation of separate communication links and ground support systems for multiple free-flying satellites can be overcome by using space platforms and multiplexing the data streams. Pertinent features of the space shuttle orbiter payloads, the solar power satellite, and geostationary and geosynchronous platforms are discussed. Typical payload requirements data which are needed to allow meaningful study of payloads as candidates for platform implementation are cited and factors affecting the compatibility/grouping of payloads are outlined. A R H

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## INTERACTIVE ANALYSIS AND DESIGN

Includes computerized technology design and development programs, dynamic analysis techniques, thermal modeling, and math modeling

**A79-34516** \* Stability analysis of a flexible spacecraft with a sampled-data attitude sensor. S. Garg (Toronto, University, Toronto, Canada). *Journal of Guidance and Control*, vol. 2, May-June 1979, p. 169-172. 7 refs. Research supported by the National Research Council of Canada.

The pitch attitude control system for a flexible communications satellite is analyzed using sampled-data techniques. The sampling arises mainly from the use of discrete-time attitude measurement rather than from the digital controller implementation. It is found that Nyquist techniques lead to a relatively simple stability analysis that models the multirate sampling process with considerable fidelity, eliminating guesswork associated with equivalent delays. Controller modifications that improve stability are arrived at by this route. Finally, flexible-mode frequency and damping are varied to evaluate their influence on stability. There seems to exist a critical frequency at which stability margins are very small. Increasing the damping, predictably, improves matters. (Author)

**A79-34732** \* Large Advanced Space System (LASS) Computer Program. A. F. Leondis (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 254-261. (AIAA 79-0904)

The LASS Computer Program was undertaken to provide a systems-oriented computer capability to rapidly synthesize, evaluate, derive performance characteristics and estimate costs for large advanced space satellites. The LASS program contains structure simulators that can detail all 6,030 struts of a 30-bay tetrahedral dish in minutes, or, if instructed to do so, will use the Tetrahedral Truss Simplification Analogy to model a dish of any size with any number of bays as a simpler structure. Rigid-body control equations are used to determine propellant and momentum exchange equipment masses. A number of load conditions are solved, including the dynamic responses due to an applied thrust as well as thermal loads and distortions. (Author)

**A79-34740** \* Thermal control design analysis of an on-orbit assembly spacecraft. R. F. O'Neill (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 324-332. (AIAA 79-0917)

Design requirements for large space structures such as the DOD/STS On-Orbit Assembly (OOA) spacecraft include stringent limitations on maximum allowable thermally induced structural deflections. The present paper describes a methodical, building block approach to the thermal design analysis of the OOA spacecraft. A rationale is developed for selecting worst-case space environments and spacecraft orientations. The Vector Sweep computer program was used in computing shadowed incident heat flux histories for subsequent thermal analysis of the OOA spacecraft structures. The thermal response of typical structural elements is presented. B.J.

**A79-37100** \* Calculated scan characteristics of a large spherical reflector antenna. P. K. Agrawal, W. F. Croswell (NASA, Langley Research Center, Hampton, Va.), and J. F. Kauffman (North

Carolina State University, Raleigh, N.C.). *IEEE Transactions on Antennas and Propagation*, vol. AP-27, May 1979, p. 430, 431. 5 refs.

A previously published numerical method to calculate the radiation properties of parabolic reflectors has been modified to also include very large spherical reflectors. The method has been verified by comparing the calculated and the measured results for a 120-wavelength spherical reflector. (Author)

**A79-38031** \* Thermal control of a spacecraft deployable lattice boom. J. J. Chapter (Martin Marietta Aerospace, Denver, Colo.). *American Institute of Aeronautics and Astronautics, Thermo physics Conference, 14th, Orlando, Fla., June 4-6, 1979, Paper 79-1047* 8 p. 6 refs.

Long appendages or booms are required for spacecraft experiment probes, antennae, and gravity-gradient stabilization. Booms may extend hundreds of feet, and solar heating can result in thermal distortion and spacecraft attitude-control problems. The lattice boom analyzed in the present studies is constructed of graphite-epoxy longirons coupled by crossbow members with the assembly covered with a Kapton membrane. Analysis of the dynamic behavior of a boom is complex because it requires the coupling of thermal and mechanical phenomena. Two FORTRAN subroutines that together determine the temperature response of a graphite-epoxy Kapton lattice boom have been developed for use in a dynamic bending and thermal-distortion analysis computer program. Subroutine Q calculates the boom incident solar heat flux, whereas subroutine TEMP, a simplified thermal analyzer, calculates the boom temperature response. The validity of the thermal analysis subroutines has been substantiated by correlation with thermal vacuum test data. (Author)

**A79-52555** \* Modal truncation for flexible spacecraft. P. C. Hughes (Toronto, University, Toronto, Canada) and R. E. Skelton (Purdue University, West Lafayette, Ind.). *American Institute of Aeronautics and Astronautics, Guidance and Control Conference, Boulder, Colo., Aug. 6-8, 1979, Paper 79-1765* 8 p. 14 refs.

A hierarchy of dynamical models is identified for large non-spinning flexible spacecraft. At each level, techniques are explained for reducing the order of the model before proceeding to the next level. These techniques have in common the presupposition that the model has at each state been expressed in terms of its natural modes, some of which can if necessary be deleted based on the evaluation of one or more of the quantitative criteria proposed. These criteria are based on insights from several different perspectives, including inertial completeness, frequency relationships, controllability and observability considerations, and the contributions of individual modes to a mission-dependent cost functional (modal cost analysis). With the aid of these criteria, many of the engineering judgments related to model order reduction can be made on a rigorous quantitative basis. (Author)

**A79-52741** \* Derivation of the equations of motion for complex structures by symbolic manipulation. A. L. Hale and L. Medovitch (Virginia Polytechnic Institute and State University, Blacksburg, Va.). *Computers and Structures*, vol. 9, Dec. 1978, p. 639-649. 10 refs. Grant No. NCG 1114

This paper outlines a computer program especially tailored to the task of deriving explicit equations of motion for structures with point connected substructures. The special purpose program is written in FORTRAN and is designed for performing the specific algebraic operations encountered in the derivation of explicit equations of motion. The derivation is by the Lagrangian approach. Using an orderly kinematical procedure and a discretization and/or truncation scheme, it is possible to write the kinetic and potential energy of each substructure in a compact vector matrix form. Then, if each element of the matrices and vectors encountered in the kinetic and potential energy is a known algebraic expression, the



## 02 INTERACTIVE ANALYSIS AND DESIGN

computer program performs the necessary operations to evaluate the kinetic and potential energy of the system explicitly. Lagrange's equations for small motions about equilibrium can be deduced directly from the explicit form of the system kinetic and potential energy. (Author)

**A79-53299** Dynamic qualification of large space structures by means of modal coupling techniques. A. Bertram (Deutsche Forschungs- und Versuchsanstalt für Luft und Raumfahrt, Institut für Aerodynamik, Göttingen, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-107*. 12 p. 8 refs.

In this paper some problems are described which are expected to arise during dynamic qualification of future large space structures. It is shown that the methods applied today are no longer sufficient. As conclusion, the concept of a qualification procedure is proposed, which considers the phase of launching, as well as the phase of mission in orbit. (Author)

**A79-53346** General dynamics of a large class of flexible satellite systems. K. W. Lips and V. J. Modi (British Columbia University, Vancouver, Canada). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-182*. 16 p. National Research Council of Canada Grant No. A 2181

The paper presents a general formulation for librational dynamics of satellites with an arbitrary number, type and orientation of deploying flexible appendages. In particular, the case of beam-type flexible appendages deploying from a satellite in an arbitrary orbit is considered. The governing nonlinear, nonautonomous and coupled equations for vibration of the appendages and libration of the satellite are integrated numerically. Several cases of practical importance are considered making the system progressively more general and hence complex: (1) planar case representing pitch and appendage oscillations in the orbital plane; (2) general attitude motion with planar vibrations of flexible members; and (3) above two cases together with the out-of-plane component of vibrations. Results show that under critical combinations of the system parameters the combined effect of flexibility and deployment can be substantial. (Author)

**N79-22178\*** Aerojet ElectroSystems Co., Azusa, Calif. **SPACE STATION THERMAL CONTROL SURFACES Final Report**

C. R. Maag, J. M. Millard, J. A. Jeffery, and R. R. Scott. Apr. 1979. 387 p. refs.

(Contract NAS8-32637)

(NASA-CR-161217, Rept. 5836)

Avail. NTIS

HC A17/MF A01 CSCL 22B

Mission planning documents were used to analyze the radiator design and thermal control surface requirements for both space station and 25-kW power module, to analyze the missions, and to determine the thermal control technology needed to satisfy the sets of requirements. Parameters such as thermal control coating degradation, vehicle attitude, self eclipsing, variation in solar constant, albedo, and Earth emission are considered. Four computer programs were developed which provide a preliminary design and evaluation tool for active radiator systems in LEO and GEO. Two programs were developed as general programs for space station analysis. Both types of programs find the radiator-flow solution and evaluate external heat loads in the same way. Fortran listings are included. A. R. H.

**N79-23128\*** Cincinnati Univ., Ohio. Dept. of Aerospace Engineering and Applied Mathematics

## GEOMETRIC MODEL AND ANALYSIS OF ROD-LIKE LARGE SPACE STRUCTURES

A. H. Nayfeh and M. S. Hefney [1978]. 64 p. refs.

(Grant NSG-1185)

(NASA-CR-158509) Avail. NTIS HC A04/MF A01 CSCL 22B

The application of geometrical schemes to large sphere antenna reflectors was investigated. The purpose of these studies is to determine the shape and size of flat segmented surfaces which approximate general shells of revolution and in particular spherical and paraboloidal reflective surfaces. The extensive mathematical and computational geometry analyses of the reflector resulted in the development of a general purpose computer program. This program is capable of generating the complete design parameters of the dish and can meet stringent accuracy requirements. The computer program also includes a graphical self contained subroutine which graphically displays the required design. G. Y.

## N79-24027\* Grumman Aerospace Corp., Bethpage, N.Y. ENVIRONMENTAL INTERACTION IMPLICATIONS FOR LARGE SPACE SYSTEMS

E. Miller, W. Fischbein, M. C. Stauber, and P. K. Suh. In NASA Lewis Res. Center. Spacecraft Charging Technol., 1978. 1979 p. 388-407

Avail. NTIS HC A99/MF A01 CSCL 22B

Large Space Systems (LSS) comprise a new class of spacecraft, the design and performance of which may be seriously affected by a variety of environmental interactions. The special concerns associated with spacecraft charging and plasma interactions from the LSS designer's viewpoint are addressed. Survivability of these systems under combined solar U.V., particle radiation and repeated electrical discharges is of primary importance. Additional questions regard the character of electrical discharges over very large areas, the effects of high current/voltage systems and magnitude of induced structural disturbances. A concept is described for a large scale experiment platform. G. Y.

## N79-33500\* National Aeronautics and Space Administration, Langley Research Center, Hampton, Va. LOAD CONCENTRATION DUE TO MISSING MEMBERS IN PLANAR FACES OF A LARGE SPACE TRUSS

Joseph E. Waltz. Washington, Oct. 1979. 39 p. refs.

(NASA-TP-1522, L-12872) Avail. NTIS HC A03/MF A01

CSCL 20K

A large space structure with members missing was investigated using a finite element analysis. The particular structural configuration was the tetrahedral truss, with attention restricted to one of its planar faces. Initially the finite element model of a complete face was verified by comparing it with known results for some basic loadings. Then an analysis was made of the structure with members near the center removed. Some calculations were made on the influence of the mesh size of a structure containing a hexagonal hole, and an analysis was also made of a structure with a rigid hexagonal insert. In general, load concentration effects in these trusses were significantly lower than classical stress concentration effects in an infinitely wide isotropic plate with a circular rigid inclusion, although larger effects were obtained when a hole extended over several rings of elements. Author

## 03 STRUCTURAL CONCEPTS

Includes erectable structures (joints, struts, and columns), deployable platforms and booms, solar sail, deployable reflectors, space fabrication techniques and protrusion processing

**A79-34745 \*** **Expandable modules for large space structures.** J. M. Hedgespeth (As. o Research Corp., Carpinteria, Calif.) and M. M. Mikulas (NASA, Langley Research Center, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 375-379. Contract No. NAS1-14887 (AIAA 79-0924)

There is a need for means to construct large complex structures without having to spend a large amount of time for assembly. One approach to meeting this requirement is to erect the overall structure using highly efficient structural modules. The individual modules can then be packaged for launch, so as to utilize the volume of the Shuttle properly, and then expanded in orbit. The present paper describes several types of such modules that have been designed and tested.

B.J.

**A79-34746 \*** **Large solid deployable reflector.** W. B. Palmer and M. M. Griebler (TRW Defense and Space Systems Group, Redondo Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 380-389. (AIAA 79-0925)

A deployment concept has been developed for large, solid surface, high accuracy antenna reflectors. The design consists of a variable number of deployable panels hinged from a fixed center section. The panels are permanently hinged to each other to minimize thermal distortion and to ensure accuracy upon deployment. A maximum error of .005 inch 1/2 path length RMS has been predicted for a 16 ft reflector, due to both thermal distortion and manufacturing tolerances. Analysis of a 24 ft reflector by computer graphics and finite element modeling has included calculation of stowed and deployed deflections and natural frequencies. A restoring mechanism and contour measurement techniques have also been examined.

(Author)

**A79-34748 \*** **Deployable multi-payload platform.** L. M. Jenkins (NASA, Johnson Space Center, Spacecraft Design Div., Houston, Tex.) and F. C. Runge (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 400-408. (AIAA 79-0928)

Many space payloads with similar mission requirements can be grouped and accommodated on an orbiting platform which provides high-capacity, centralized services. Various concepts for such a platform were devised and evaluated to identify optimal features, interface prospects and areas of technological challenge. Guidelines included minimum and augmented mission models for science and applications payloads for the 1985-90 time period, minimum extension of the Orbiter capability, maximum use of the Orbiter remote manipulator system and capitalization on EVA where applicable. Deployable structures were employed to provide spacious payload berthing on a platform which can be highly compacted for shuttle delivery.

(Author)

**A79-34749 \*** **Erectable platform for science and applications payloads circa 1985.** F. A. Zyhus (Rockwell International Corp., Satellite Systems Div., Pittsburgh, Pa.) and L. Knafl (NASA, Langley Research Center, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 409-416. (AIAA 79-0931)

A program involving the development of one or more free flying platforms for earth orbit to provide accommodations and operational services to space science and applications payloads is described. An overview is presented of studies carried out to select a specific platform and utilities module concept, its subsystems, and the means by which services are supplied to dependent science and applications mission equipment. Some examples are given of candidate research and technology programs that support development of the platform system.

B.J.

**A79-34750 \*** **Deployable antenna technology development for the Large Space System Technology program.** R. E. Frieland (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.) and T. G. Campbell (NASA, Langley Research Center, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 417-428. 21 refs. Contract No. NAS7-100 (AIAA 79-0932)

The critical technologies associated with the development of deployable reflector antenna technology for the LSST program will be derived from NASA mission models and the subsequent requirements will be related to the classes of missions involved. The approach formulated for the development of reflector technology is based on the development of specific reflector concepts that have been identified as leading candidates for future applications. The development approach will be augmented by supporting technology disciplines such as controls, materials, electromagnetic analysis, as well as the capability of analytically predicting the overall performance of the large space system.

B.J.

**A79-34751 \*** **Post fabrication contour adjustment for precision parabolic reflectors.** J. S. Archer (TRW Defense and Space Systems Group, Redondo Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 429-437. 5 refs. (AIAA 79-0933)

Post fabrication adjustment is an effective procedure for attaining high precision in the fabrication and assembly of parabolic reflectors. This technique has been applied to fixed solid surface, deployable rib-mesh and deployable solid surface reflectors. Contour adjustment to minimize the contour rms can be performed at any stage of the fabrication, subsystem integration, deployment and assembly in low earth orbit (LEO) or during free flight on orbit operational checkout. When coupled with the use of graphite epoxy construction, this capability could lead to the development of reflectors capable of operating at frequencies from 100 to 1000 GHz.

(Author)

**A79-34753 \*** **Maypole/Hoop/Column/deployable reflector concept development for 30 to 100 meter antenn.** B. C. Tankersley (Harris Corp., Melbourne, Fla.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 446-458. (AIAA 79-0935)

The hoop/column, a tensioned structure of the maypole class, is intended for applications in the 30-100 meter diameter range. Pack-



### 03 STRUCTURAL CONCEPTS

aging constraints consistent with the Space Shuttle transportation capability necessitate a unique concept to deploy and stabilize the large mesh reflective surface. A NASA LePC sponsored program is currently underway to develop this concept through preliminary design. B.J.

**A79-34756** \* An approach toward the design of large diameter offset fed antennas. A. A. Woods, Jr., and W. D. Wade (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 475-480. (AIAA 79-0938)

A desire for maximum efficiency in space antennas is placing emphasis on the application of offset fed antennas. Lockheed Missiles and Space Company has been investigating the application of the wrap-rib design in the offset geometry antenna configuration. The basic technology developed over the previous 15 years on deployable antennas is directly applicable with relatively minor modifications required in the area of rib, or surface support, manufacturing and constraints on feed tower/reflector support booms. This basic wrap-rib design approach for large apertures as applied to both the symmetric and offset configurations is discussed and performance/growth capability presented. (Author)

**A79-34758** \* Large multibeam space antennas. P. Foldes (General Electric Co., Space Div., Valley Forge, Pa.) and M. W. Dienemann (General Electric Co., ReEntry and Environmental Systems Div., Philadelphia, Pa.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 493-502. (AIAA 79-0942)

Large multibeam space antennas requiring sophisticated beam-forming networks, accurate figure control, and reconfigurability to accommodate changing data flow and provide beam control are envisaged as commonplace in the next 10 years. It is shown that these multibeam antenna systems require technology development in the areas of large offset fed parabolic reflectors to reduce beam blockage, accurate reflector surface contours to maintain beam isolation, low thermal gradient control to reduce defocusing errors, and active real time beam shape control. B.J.

**A79-46062** \* Optimization of triangular laced truss columns with tubular compression members for space application. C. H. Yoo (Marquette University, Milwaukee, Wis.). *AIAA Journal*, vol. 17, Aug. 1979, p. 921-924. 8 refs.

Minimum weight optimization procedures are considered for a tubular laced column, one of the most weight efficient components of large space structures. The procedures are based on designing for a column with initial imperfections. The optimum design procedures are applied to the example of a graphite epoxy column 10 500 m long and subjected to loading from 1000 N to 25 000 N with initial imperfection ratios ranging from 0.0004. B.J.

**A79-53261** Solar thermal aerostat research station /STARS/. E. C. Okress and R. K. Soberman (Franklin Institute, Franklin Research Center, Philadelphia, Pa.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-35*. 12 p. 14 refs.

The paper introduces the concept of a large, constant volume, solar powered, warm air, spherical rigid navigable aerostat able to remain aloft in the stratosphere for many years. Equipped with compressed stratospheric air for energy storage, it will be capable of performing, on a 24 hour basis, a wide variety of missions, including surveillance, solar energy generation and radiation or particle beam

transmission to the surface, environmental monitoring, local weather modifications, long-range communications and microwave power relay, nighttime target illumination, weapons platform of high energy requirements, platform for aircraft launch and recovery, platform for space hardware and reusable spacecraft catapult launching, etc. Most, if not all, of these numerous missions may be conducted simultaneously, due to the unprecedented lift capability of the proposed stratoscraft. With solar energized compressed air and electric thrusters, it will be capable of 24 hours navigation and hovering in the stratosphere in most regions about the earth, and throughout the year, for many (e.g., about 10) years. (Author)

**A79-53298** \* Construction of large space structures. J. F. Garbotti, A. J. Conway, Jr., R. Johnson, Jr. (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.), and T. J. Dunn (NASA, Johnson Space Center, Houston, Tex.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-106*. 15 p. 5 refs.

The paper examines a construction capability to build large structures in space, its use in conjunction with the Shuttle Orbiter and a large Space Construction Base, and its relationship to system performance and cost. The geodetic beam design using a tetrahedral truss structure and reinforced plastics and its structural analysis, tests of demonstration cylinders, and preliminary machine design are discussed. The geodetic structure is shown to have high buckling stability, low thermal distortion, high stiffness, and its simple shape permits high production-rate automatic fabrication. The geodetic beam fabrication machine which will automatically fabricate cylindrical beams in space from earth prefabricated rods, and on-orbit beam and platform fabrication are described. Preliminary results of system performance and cost studies indicate that on-orbit fabrication using a small geodetic beam machine can be economically superior to the deployable and erectable modes of construction for many near term applications. A.T.

**A79-53360** Large geostationary communications platform. W. L. Morgan (COMSAT Laboratories, Clarksburg, Md.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-210*. 14 p. 9 refs. Research sponsored by the Communications Satellite Corp.

This paper reviews the large space structure concepts variously known as orbital antenna farms, geostationary platforms, or space stations. It does not advocate any one position, but provides a balanced overview of the present situation. As is typical of all new technologies, various approaches to such a large project are being considered, and their distinctive features are highlighted. This paper also estimates the communications satellite capacity which will be required by the year 2000. The various options available to the designer are reviewed in the following areas: low earth orbit operations, the ascent to the geostationary earth orbit, initial deployment on orbit, and the communications growth requirements. (Author)

**A79-53361** Lightweight deployable microwave satellite antennae - Needs, concepts and related technology problems. D. Fasold, L. Heichele, and W. Schaefer (Messerschmitt Bolkow-Bohm GmbH, Ottobrunn, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-211*. 17 p. 13 refs. Deutsche Forschungs- und Versuchsanstalt für Luft und Raumfahrt Contract No. 01-TB-047-AK/RT/WRT 20.

Technology of a microwave satellite parabolic reflector antennae is examined. Microwave antennae with high pointing accuracy, high directivity and/or small beam width will be required for communication satellites of the second generation, and parabolic antennae with aperture diameters up to 30 meters fulfill these RF requirements.

Weight and size constraints of spacecraft structures will require light-weight deployable antennae, illustrated by petal and mesh reflector concepts. Selection criteria, most suitable reflector concepts, the mesh manufacturing technology, and measurement of mesh RF properties are discussed. Mesh adjustment technology, accurate CFRP panel manufacturing, and deployment and locking devices of very high accuracy are shown. The deployable mesh reflector appears most promising, and reflection measurements of mesh samples at 12 and 18 GHz are analyzed. A T

**A79-53404\*** Communication architecture for large geostationary platforms. F. E. Bord (Aerospace Corp., El Segundo, Calif.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979* Paper 79-300. 17 p. 6 refs. Contract No. NAS8-32281.

Large platforms have been proposed for supporting multi-purpose communication payload: in rapid economy of scale, reduce congestion in the geostationary orbit, provide interconnectivity between diverse earth stations, and obtain significant frequency reuse with large multibeam antennas. This paper addresses a specific system design, starting with traffic projections in the next two decades and discussing tradeoffs and design approaches for major components including antennas, transponders, and switches. Other issues explored are selection of frequency bands, modulation, multiple access, switching methods, and techniques for servicing areas with nonuniform traffic demands. Three major services are considered: a high-volume trunking system, a direct-to-user system, and a broadcast system for video distribution and similar functions. Estimates of payload weight and d.c. power requirements are presented. Other subjects treated are: considerations of equipment layout for servicing by an orbit transfer vehicle, mechanical stability requirements for the large antennas, and reliability aspects of the large number of transponders employed. (Author)

**N79-22563\*** General Dynamics/Convair, San Diego, Calif. **DEVELOPMENT OF A BEAM BUILDER FOR AUTOMATIC FABRICATION OF LARGE COMPOSITE SPACE STRUCTURES**

John G. Bodie. In: NASA Johnson Space Center. The 13th Aerospace Mech. Symp. 1979. p. 293-304. ref.

Avail. NTIS HC A13/MF A01 CSCL 22B

The composite material beam builder which will produce triangular beams from pre-consolidated graphite/glass/thermoplastic composite material through automated mechanical processes is presented. Side member storage, feed and positioning, ultrasonic welding, and beam cutoff are formed. Each process lends itself to modular subsystem development. Initial development is concentrated on the key processes for roll forming and ultrasonic welding composite thermoplastic materials. The construction and test of an experimental roll forming machine and ultrasonic welding process control techniques are described. S E S

**N79-24086\*** Boeing Aerospace Co., Seattle, Wash. **DESIGN FABRICATION AND TEST OF GRAPHITE/POLYIMIDE COMPOSITE JOINTS AND ATTACHMENTS FOR ADVANCED AEROSPACE VEHICLES** Quarterly Technical Progress Report, 15 Jan. 1979

15 Apr. 1979. 41 p. refs.

(Contract NAS1-15644)

(NASA-CR-159080, QTPR-1) Avail. NTIS HC A03/MF A01 CSCL 11D

Graphite/polyimide (G/P) bolted and bonded joints were investigated. Possible failure modes and the design loads for the four generic joint types are discussed. Preliminary sizing of a type 1 joint, bonded and bolted configuration is described, including assumptions regarding material properties and sizing methodology. A general purpose finite element computer code is described that was formulated to analyze single and double

lap joints, with and without tapered adherends, and with user-controlled variable element size arrangements. An initial order of Celcon 6000/PMR 15 prepreg was received and characterized. J M S

**N79-25425\*** National Aeronautics and Space Administration Langley Research Center, Hampton, Va.

**FOLDABLE BEAM Patent Application**

John M. Hedgepeth (Astro Research Corp., Carpinteria, Calif.), John V. Coyner (Astro Research Corp., Carpinteria, Calif.), and Robert F. Crawford, inventors (to NASA) (Astro Research Corp., Carpinteria, Calif.). Filed 23 Feb. 1979. 15 p. Sponsored by NASA.

(NASA Case LAR 12077.1, US-Patent Appl. SN 014663) Avail. NTIS HC A02/MF A01 CSCL 20K

The invention is used in cases where a conventional solid beam is unsuitable specifically where transportation to the use site requires a more lightweight or compact structure. Ease of deployment is another object. Construction of antennae or platforms in outer space is such a case. The novelty of the invention lies in the use of hinged segments in conjunction with cables, whereby a collapsed assembly of lightweight tubular struts may be readily deployed simply by applying tension to the cables, and just as easily stowed by loosening the cables.

Official Gazette of the U.S. Patent and Trademark Office

**N79-29203\*** General Dynamics/Convair, San Diego, Calif. **SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY (SCAFEDS), PART 3. VOLUME 2: STUDY RESULTS Final Report**

29 Jun. 1979. 309 p. refs.

(Contract NAS9-15310)

(NASA-CR-160288, CASD-ASP78-016 Vol. 2) Avail. NTIS HC A14/MF A01 CSCL 22A

The detailed results of all part 3 study tasks are presented. Selected analysis was performed on the beam builder conceptual design. The functions of the beam builder and a ground test beam builder were defined. Jig and fixture concepts were developed and the developmental plans of the beam builder were expounded. R E S

**N79-29213\*** Grumman Aerospace Corp., Bethpage, N.Y. **SPACE FABRICATION DEMONSTRATION SYSTEM, TECHNICAL VOLUME Final Report**

15 Mar. 1979. 117 p.

(Contract NAS8-32472)

(NASA-CR-161286, NSS-SFDS-RP013) Avail. NTIS HC A06/MF A01 CSCL 22A

The automatic beam builder ABB was developed, fabricated, and demonstrated within the established contract cost and schedule constraints. The ABB demonstrated the feasibility of producing lightweight beams automatically within the required rate of 1 to 5 ft of completed beam per minute and producing structurally sound beams with axial design load of 5538 N based on the Grumman photovoltaic satellite solar power system design reference structure. Author

**N79-29214\*** Grumman Aerospace Corp., Bethpage, N.Y. **SPACE FABRICATION DEMONSTRATION SYSTEM: EXECUTIVE SUMMARY Final Report**

15 Mar. 1979. 35 p.

(Contract NAS8-32472)

(NASA-CR-161287, NSS-SFDS-RP013) Avail. NTIS HC A03/MF A01 CSCL 22A

The results of analysis and tests conducted to define the basic 1-m beam configuration required, and the design, development, fabrication, and verification tests of the machine required to automatically produce these beams are presented. M M M

### 03 STRUCTURAL CONCEPTS

**N79-30604j** Construcciones Aeronauticas S.A., Madrid (Spain)  
Space Div

**STUDY OF HIGH STABILITY STRUCTURAL SYSTEMS:  
PRE-PHASE A Final Report**

Paris: ESA, 29 Sep 1978. 160 p. refs.

(Contract ESTEC-3398/77/NL-PP(SC))

(DT-HSS-5, ESA-CRIP-1164) Avail: NTIS HC A08/MF A01

The feasibility of large, high stability, flat, deployable antennas for earth resources observation was studied. A synthetic aperture radar antenna, 10 meters long by 1 meter wide, was taken as a representative structure of this type. Requirement definitions, interface design constraints, and a trade-off analysis of different solutions were considered. Possible design concepts and an analysis of the thermal loads were studied. Due to the different possibilities of the design configurations, strongly depending on some not well defined interfaces during development, the mechanical behavior of the presented designs are omitted or studied in a simplified manner. Author (ESA)

**N79-31314j** Dornier Werke GmbH, Friedrichshafen (West Germany)

**DEVELOPMENT OF A MOVABLE, THERMALLY CONDUCTING JOINT FOR APPLICATION TO DEPLOYABLE RADIATORS**

B. Hindener and C. J. Savage (ESTEC). In: ESA, Spacecraft Thermal and Environ. Control Systems, Oct 1978, p. 449-452.

Avail: NTIS HC A99/MF A01

The development of a thermal joint concept for radial heat transfer from a fixed feeder to a deployable radiator is presented. A critical comparison of several imaginable techniques considered from thermal and mechanical points of view shows that most favorable results with regard to thermal efficiency and low deployment torques can be expected using a mixture of conductive grease and silver powder as interface filler between feeder and rotor. The design of a technological model based on these investigations is described and the results of a thermal vacuum test are given. Radial temperature drops and measured torques proved to be acceptable within the required ranges of temperature and radial heat flux density. Author (ESA)

## CONTROL SYSTEMS

Includes new attitude and control techniques, improved surface accuracy measurement and control techniques.

**A79-34523** \* Direct velocity feedback control of large space structures. M. J. Bolas (Bolt Beranek and Newman, Inc., Cambridge, Mass.). *Journal of Guidance and Control*, vol. 2, May-June 1979, p. 252, 253. 5 refs.

A method, called direct velocity feedback, for active vibration suppression of large space structures is presented. Output signals from velocity sensors are electronically multiplied by gains and these signals are directly fed back to collocated force actuators. The DVFB controller cannot destabilize the system provided that (1) the number of collocated force actuators is equal to the number of velocity sensors, (2) the feedback gain matrix is nonnegative definite, and (3) if zero frequency modes exist, the actuators must maintain constant energy in these modes. A large symmetric eigenvalue calculation is set up but not carried through for determining the actual pole locations of the closed-loop system. P.T.H.

**A79-34743** \* Electrostatically formed antennas. D. J. Mihora and P. J. Redmond (General Research Corp., Santa Barbara, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 354-365. 7 refs. Contract No. NAS1 15548; Grant No. DASG60-77 C-0123. (AIAA 79-0922)

The electrostatically controlled membrane mirror (ECMM) is a way to achieve large, very light reflectors for radar, radio astronomy, radiometry, and optical devices. The concept is that of using electrostatic forces to tension a thin conducting membrane and to maintain it in a precision antenna shape. The ECMM is an adaptive structure which maintains surface quality despite errors in construction, irregularities of materials, solar heating, and onboard disturbances. The combination of high gain and low mass makes the ECMM ideally suited for space applications. B.J.

**A79-34744** \* The dual-momentum control device for large space systems. R. C. Montgomery (NASA, Langley Research Center, Flight Dynamics and Control Div., Hampton, Va.) and C. R. Johnson, Jr. (NASA, Langley Research Center, Hampton; Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 366-374. 9 refs. (AIAA 79-0923)

The dual-momentum control device being studied for large spacecraft consists of two counter-rotating rings, each designated as an orbital momentum control device (AMCD). For large rings, flexibility is appreciable and it becomes necessary to account for the distributed nature of the rings in the design of the magnetic bearing controllers. Also, ring behavior is unpredictably sensitive to ring temperature, spin rate, manufacturing imperfections, and other variables. For that reason, an adaptive control system is being sought for ring stabilization and maneuvering. This paper details an original adaptive control methodology for distributed parameter systems and illustrates this technique by application to AMCD stabilization. (Author)

**A79-34747** \* Control of large space structures using equilibrium enforcing optimal control. R. J. Benhabib and R. P. Iwens (TRW Control and Sensor Systems Laboratory, Redondo Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 380-399. 11 refs. (AIAA 79-0927)

Weighting matrices in the performance index of a linear optimal regulator are selected so as to minimize the excitation of residual modes of large space structures. Even though this design technique is successful with respect to spillover, an extremely sensitive controller results which becomes unstable for small perturbations in the assumed frequencies of the controlled modes. It is shown how the sensitivity of the controller to modeling errors can be reduced. Finally, it is shown how stability theory developed for distributed control of large scale systems can be used to test the a priori stability of control systems for large space structures. B.J.

**A79-34752** \* A self pulsed laser ranging system under development at JPL. M. Berdahl (California Institute of Technology, Jet Propulsion Laboratory, Applied Mechanics Div., Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 438-445. 9 refs. Contract No. NAS7 100. (AIAA 79-0934)

The performance of large space deployable antenna reflectors to be used for broad-band communications systems is largely dependent on the accuracy with which the surface figure can be constructed and maintained. The paper examines various surface distortion tolerance and measurement requirements for various classes of communication antennas. Several surface measuring methods are described including a self pulsed laser ranging system. B.J.

**A79-34755** \* Surface accuracy measurement system deployable reflector antenna. R. S. Newwander (TRW Defense and Space Systems Group, Redondo Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 467-474. Contract No. NAS1 15520. (AIAA 79-0937)

Conceptual optical sensor configurations for measuring the surface deformations of large, deployable space antennas are described. These antennas include precision deployable reflectors up to 30 meters diameter and 1000 GHz frequency and mesh deployable reflectors up to 100 meters diameter and 30 GHz frequency. For each representative antenna configuration, the surface deformation sensor provides continuous, real-time measurements at a sufficient number of sample points to be compatible with active surface control. Moreover, the sensor system does not interfere with the mechanical or microwave characteristics of either the antenna surface or the feed. For the applications considered, the sensor system consists of a central receiver ring containing six to ten long focal length, angle measuring instruments, each viewing a dedicated set of bright point targets at the antenna. The targets, either light emitting diodes or illuminated retroreflectors, are modulated to eliminate errors from spurious backgrounds. Very preliminary performance estimates indicate that the sensor system, using commercial grade components, can produce a 20th to a 30th wavelength accuracy (3 signal). (Author)

**A79-34763** \* Nonreflective boundary control of a vibrating string. A. K. Caglayan (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 535-539. 11 refs. Grant No. NSG 1527. (AIAA 79-0950)

One of the important applications in the developing Large Space Systems Technology will be the electrostatically controlled membrane mirror antenna. A high level of surface quality is achievable using electrostatically tensioned membranes in which surface accu-

## 04 CONTROL SYSTEMS

ray is obtained through active control. Electrostatic actuators behind the membrane surface would provide a means of obtaining the prescribed surface shape and also be utilized to suppress the structural vibrations in the system. The surface quality, in this case, would be limited by the size, force field shape, and the number of the electrostatic actuators. An additional control capability is to introduce boundary control at the membrane perimeter. Using this additional control mechanism, structural vibrations can be absorbed at the boundary without being reflected back into the interior regions of the membrane antenna. In this paper, boundary control of a vibrating string is studied. For this system, a nonreflective boundary control is developed in which waves reaching the boundary are absorbed by the appropriate control movement of the boundary. The control is closed loop and utilizes a single measurement close to the boundary. The closed loop control is a delay of the measurement. The delay is determined by the velocity of wave propagation in the string and the location of the sensor. (Author)

**A79-34765** \* Long interface docking for large space structure assembly. R. B. Rice (Martin Marietta Aerospace, Denver, Colo.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979. Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 546-549. (AIAA 79-0954)

The control system and resultant dynamics for a large space structure during autonomous assembly is presented. Mission and system configurations are discussed in addition to details of reaction control system and dock servos. Simulation results are given for a representative structure showing convergence, damping characteristics, and flexible body mode effects for long interface docking in space. (Author)

**A79-34766** \* Stability and control of future spacecraft systems. S. Z. Scrimay (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979. Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 550-557. (AIAA 79-0964)

A brief review is presented of some of the problem areas associated with large space structures and some of the approaches currently being taken to find solutions are discussed. Consideration is given to such areas as control system analysis, design and implementation, and those aspects of structural modeling related to control system design. (Author)

**A79-34767** \* Attitude control requirements for future space systems. J. B. Dahlgren and R. S. Edmunds (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979. Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 558-562. (AIAA 79-0951)

Landolt D and the Large Space Telescope represent current state-of-the-art systems with precise requirements placed on attitude control. Future systems for planetary stations, high precision earth monitoring and large precision deployable and erectable platforms project still more severe constraints and requirements on attitude control, including the requirement for many enabling and highly enhanced technologies beyond current state of the art. Two trend projections are identified for the areas of (1) precision pointing systems for earth orbiters and planetary spacecraft and (2) onboard high-capacity fast controllers for distributed control systems. (Author)

**A79-36189** \* Attitude control by solar sailing - A promising experiment with OTS-2. U. Renner (ESA, Communication Satellite Dept., Noordwijk, Netherlands). *ESA Journal*, vol. 3, no. 1, 1979, p. 35-40.

With solar arrays generally deformed by internal stresses, a spacecraft such as the geostationary OTS-2 communication satellite is subject to solar pressure torques. Consequently it is suggested to use solar pressure as a source of control torque for compensating a disturbance torque. In typical solar array maneuver one array continues to track the sun, while the other array drive is disabled until a predetermined array angle is reached. Then the array drive loop is re-enabled with the array reaching its normal position. According to the orbit test, the OTS-2 attitude was controlled entirely by solar sailing for almost six days while all the spacecraft's thrusters were disabled. Whereas the basic operating principles - step size, duty cycle and pointing accuracy - are comparable with those of a standard thruster control system, solar sailing has a number of advantages: saving of thrusters and fuel, inherent nutation damping and smooth operation throughout maneuvers. Potential disadvantages are: temporary reduction in solar array power and increase in the acquisition duty of the solar array drive. (Author)

**A79-37287** Observability measures and performance sensitivity in the model reduction problem. R. E. Skelton (Purdue University, West Lafayette, Ind.). *International Journal of Control*, vol. 29, Apr. 1979, p. 541-556. 13 refs.

A model reduction problem (MRP) is related to the control problem by use of a 'model quality index' which measures the performance of the higher-order system when the control is based upon a lower-order model. By truncating modal coordinates which have smaller sensitivity to the model quality index a first approximation to the MRP is obtained. Another approximation to the MRP is obtained by truncation of modal coordinates which have smaller sensitivities to the first term in the model quality index, called the 'cost of information'. Several theorems relate the scalar measures of observability of each modal coordinate to the first-order sensitivity of the 'cost of information' and of the model quality index. A case study with a flexible spacecraft illustrates truncation on the basis of observability measures and controllability measures. (Author)

**A79-41106** \* The dual momentum control device for large space systems - An example of distributed system adaptive control. R. C. Montgomery (NASA, Langley Research Center, Flight Dynamics and Control Div., Hampton, Va.) and C. R. Johnson, Jr. (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Annual ASEE Conference on Circuits, Systems, and Computers, 12th, Pacific Grove, Calif., November 6-8, 1978. Conference Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1979, p. 69-68. 5 refs.

One area in which large space systems require new technology is attitude control. The paper presents an adaptive control philosophy applicable to the control of distributed systems. An adaptive control system is described for stabilization of the flexible modes of a spinning ring. The system consists of a modal decomposition and identification subsystem, a gain adjustment subsystem, and a feedback control subsystem. Simulations are presented illustrating the adaptive capability of the system. The adaptive controller did produce stable results by quickly identifying the parameter differences and adjusting the feedback controller gains. (Author)

**A79-41699** \* Stability bounds for the control of large space structures. S. M. Joshi (NASA, Langley Research Center, Hampton, Va.) and N. J. Groom (NASA, Langley Research Center, Hampton, Va.). *Journal of Guidance and Control*, vol. 2, July-Aug. 1979, p. 349-351. 7 refs.

Balas (1977) has discussed the stability problem of reduced-order regulators and estimators in terms of control and observation 'spillover'. The term 'control spillover' was used to define that part



of the feedback control which excites the uncontrolled (or residual) modes, and "observation spillover" was used to define that part of the measurement which is contaminated by residual modes. In this paper, two sufficient conditions are derived via Lyapunov methods for asymptotic stability of large space structures using a class of reduced-order controllers. These conditions give allowable bounds on the spectral norms of control and observation spillover terms. The sufficient condition given by a specified inequality equation appears to be less conservative and should be useful as a design tool for the control of large space structures. S.D.

**A79-44413** Guidance and control 1979; Proceedings of the Annual Rocky Mountain Conference, Keystone, Colo., February 24-28, 1979. Conference sponsored by the American Astronautical Society. Edited by R. D. Culp (Colorado, University, Boulder, Colo.). San Diego, Calif., Univelt, Inc. (Advances in the Astronautical Sciences, Volume 38), 1979. 491 p. \$31.25.

Satellite navigation and attitude control and determination, autonomous systems in space, the NASA approach to standardization, and deployment and retrieval of Shuttle-era payloads are studied. Autonomous attitude determination systems, inertial measurement unit redundancy management, the fault-tolerant spaceborne computer (FTSC), a description and comparison of the NASA standard computers, and the multimission modular spacecraft are considered. Attention is given to precision correlating tracking requirements and opportunities for autonomous systems in space, spacecraft automated operations, the NASA multimission spacecraft modular attitude control system, and navigation and flight control in the inertial upper stage. V.T.

**A79-45351** Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. Conference sponsored by the American Institute of Aeronautics and Astronautics. New York, American Institute of Aeronautics and Astronautics, Inc., 1979. 707 p. \$65.

Papers are presented on such topics as dual digital flight control redundancy management system development, fuel-conservative guidance system for powered-lift aircraft, laser gyros in precision spacecraft attitude determination systems, and guidance law design for tactical weapons with strapdown seekers. Also considered are optimization of earth sensor thresholding techniques, a structural model of the adaptive human pilot, a method for determining the performance of a precision inertial guidance system, and adaptive modal control of large flexible spacecraft. B.J.

**A79-45380 \*** Control of large flexible space structures using pole placement design techniques. Y. W. Wu, R. B. Rice (Martin Marietta Aerospace, Denver, Colo.), and J. N. Juang (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif., Martin Marietta Aerospace, Denver, Colo.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 321-328. 19 refs. (AIAA 79-1738)

A design approach via the pole placement techniques for the class of large flexible space structures is developed. The numerical problems in pole placement algorithm, arising from large dimension systems and the extremely low frequency eigenvalues which occur in large space structure models are examined. It shows these numerical difficulties may be overcome by properly selecting the sensor/actuator locations and introducing a frequency scaling scheme. The concepts of this paper are illustrated by some numerical studies on

the linear feedback control design of a representative large spacecraft consisting of a small rigid core with ten radial booms (four booms 1000 ft long and five shorter booms 700 ft long) lying in a plane.

(Author)

**A79-45381 \*** Attitude control of agile flexible spacecraft. J. Y. L. Ho and H. A. Pounansky (Lockheed Missiles and Space Co., Inc., Guidance and Control Systems Dept., Sunnyvale, Calif.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 329-338. 5 refs. (AIAA 79-1739)

An advanced control for attitude control of agile flexible spacecraft is presented. Multiple sensors feedback information for both the equipment section and the flexible structure are used. A design procedure is outlined to determine controller gains by the pole placement method. Combination of outer loop feedback of attitude and rate and inner loop feedback of rate and acceleration is used. This advanced control design is applied to a digital multidelay flexible spacecraft simulation program. Comparison with conventional control for response performance is made. The advanced control concept is very promising to meet the fast maneuvering and fine pointing requirements for the agile flexible spacecraft. (Author)

**A79-45382 \*** Optimal local control of flexible structures. D. B. Schwachter (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 339-344. 8 refs. Contract No. NAS7-100. (AIAA 79-1740)

The steady state solution of the linear quadratic optimal control problem with the constraint that only partial state information is available for feedback is derived. This development results in a systematic and computationally efficient approach for reducing the complexity of the control law for high order systems. Numerical examples and performance evaluation of (1) a simple fourth order system, and (2) a free-free flexible beam, are included. (Author)

**A79-45383 \*** A family of sensors for the sensing of the position and vibration of spacecraft structures. R. H. Anderson, C. C. Huang, and N. E. Buhole (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 345-351. (AIAA 79-1741)

A family of laser heterodyne sensors is being developed for use in the active control of spacecraft structures. These sensors include an He-Ne distance measuring system for structures requiring accuracies to 0.1 mm and CO<sub>2</sub> distance measuring system which will measure unambiguously down to 0.01 micron. Vibration sensors based on both He-Ne and CO<sub>2</sub> laser are also being developed. All of these sensors have been breadboarded to verify performance and are in various stages of development directed toward prototype engineering models. B.J.

**A79-45384 \*** Orthogonal subspace reduction of optimal regulator order. T. Conadotti (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 352-358. 14 refs. (AIAA 79-1742)

A large system may be considered as an assembly of subsystems occupying mutually orthogonal subspaces. Using this orthogonality, an algorithm is developed for the design of optimal low-order state

## 04 CONTROL SYSTEMS

feedback regulators which control a subsystem independently of the rest of the system. Conditions are stated under which a regulator can be constructed which has zero control spillover to states which are modeled but are not to be controlled. A comparison is made between this method of control spillover reduction and the method of forced singular perturbation. Results are applicable to the study of structural vibration in large spacecraft. **B.J.**

**A79-45405** \* **Active control of certain flexible systems using distributed and boundary control.** A. K. Caglayan (Beit Benet and Neuman, Inc., Cambridge, Mass.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 529-532. 12 refs. (AIAA 79-1778)

This paper is concerned with the simultaneous utilization of boundary and interior control in large flexible spacecraft. The issue of boundary control can arise due to a given actuator placement or actuator positions can be chosen to make use of boundary control in absorbing structural vibrations. First, it is shown that boundary control can be incorporated into interior control of truncated modal control by using either integral transforms or suitable change of variables. The shortcomings of these approaches are discussed. Secondly, the recent results on nonreflective boundary control approach are summarized and interpreted. A scheme incorporating a nonreflective boundary controller along with a reduced order interior controller is proposed. (Author)

**A79-45406** \* **On adaptive model control of large flexible spacecraft.** C. R. Johnson, Jr. (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 533-539. 29 refs. Grant No. NAG 1527 (AIAA 79-1779)

A recently developed strategy for adaptive sampled-data control of distributed parameter systems based on a plant modal expansion description and modal simultaneous identification and regulation algorithms is presented with frequent reference to the angular momentum control device (AMCD) test example. The requirements of observation spillover reduction and modal eigenvector shape pre-specification, which are especially crucial to the proposed adaptive control strategy, are addressed. Individual low pass time filtering of sensed AMCD particle displacements is proposed for observation spillover reduction. A layered scheme incorporating 'eigenvector' shape improvement is outlined to combat the expansion basis pre-specification requirement. (Author)

**A79-45407** \* **Stability of distributed control for large flexible structures using positivity concepts.** R. J. Bernhuber, R. P. Ivers, and R. L. Jackson (TRW Defense and Space Systems Group, Redondo Beach, Calif.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 540-548. 17 refs. (AIAA 79-1780)

A robust stability test and associated design procedure based on the positivity of operators is proposed. The test does not rely on modal truncation or high order truth models of the structure and is independent of the numerical values of the modal data. The stability criterion is applied to the plant (structure) and the controller individually, assuring global stability when the loop is closed by negative feedback. Therefore, design/stability evaluations need only iterate on the low order controller part of the loop. The method can be extended to nonlinear systems. (Author)

**A79-45408** \* **A learning control system extension to the modal control of large flexible rotating spacecraft.** K. R. Hall (LTV Corp., Hampton, Va.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 549-557. 5 refs. (AIAA 79-1781)

A proposed attitude control device for large space structures consists of a pair of oppositely spinning rings of large diameter and small cross sectional area. This report deals with the simulation of the motion of one ring and the implementation of a control system for controlling the elastodynamic motions of the ring. A novel feature of the adaptive control system is the learning feature which allows the control system to adapt to changing conditions even in the absence of identification. The out-of-plane motion is examined in detail with simulation development and control system development both in modal representation. (Author)

**A79-47234** \* **Relative attitude of large space structures using radar measurements.** A. R. Brook (Martin Marietta Aerospace, Denver, Colo.) and A. L. Satin (Aerospace Corp., El Segundo, Calif.). American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Provincetown, Mass., June 25-27, 1979, AAS Paper 79-156. 72 p. 5 refs.

The need for accurate knowledge of relative attitude and attitude rate for station-keeping and docking of large (350 ft. diameter) space structures, is studied. It is shown that enhanced accuracy may be obtained by making use of radar measurements between the center of one structure and outlying points on the extended structure of another. In addition, the results of a covariance analysis of a sequential measurement filter are used to evaluate the adequacy of a candidate radar transponder system for station-keeping at 1000 ft and 10 ft. It is concluded for the mission in question that two transponders, capable of providing range, range-rate, azimuth and elevation data, should be located on the outlying structure of the chase vehicle near the docking interface, while a third transponder on the center column completes a minimal set suitable for long or short range tracking. (Author)

**A79-47235** \* **Large angle maneuver strategies for flexible spacecraft.** F. L. Markley (U.S. Navy, Naval Research Laboratory, Washington, D.C.). American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Provincetown, Mass., June 25-27, 1979, AAS Paper 79-156. 24 p. 8 refs.

Three maneuver strategies are considered for large angle single axis slow maneuvers of a flexible spacecraft. The spacecraft is modeled by a four component state vector consisting of the center of mass angle and angular rate and the displacement and velocity of a single flexible mode. Only one controller is used, and fixed end point constraints are imposed on the maneuver. The first strategy minimizes a quadratic function of mode displacement, mode rate, and control effort. The second strategy minimizes a quadratic function of mode displacement and mode rate only, with the control effort being bounded in magnitude. Bang bang arcs, singular arcs, and chattering arcs all appear in this case. The third strategy employs a control function that is a polynomial in time. Numerical calculations are performed for a representative case, and the performances of the three strategies are compared. (Author)

**A79-47236** \* **Decoupling control of a long flexible beam in orbit.** A. S. S. R. Reddy, P. M. Bamum (Howard University, Washington, D.C.), and H. A. Hamer (NASA, Langley Research Center, Hampton, Va.). American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Provincetown, Mass., June 25-27, 1979, AAS Paper 79-158. 26 p. 15 refs. Grant No. NAG 1414.

The paper presents a method of control for large flexible systems using state variable feedback, with a long flexible beam given as an example. These feedback gains are selected: (1) based on the decoupling of the original coordinates and to obtain proper damping and (2) by applying the linear regulator problem to the individual modal coordinates separately. It is shown that the linear control law thus obtained are then evaluated by numerical integration of the nonlinear system equations. Also included are results showing the effects (control spillover) on the uncontrolled modes when the number of controllers is less than the number of modes, and the effects of inaccurate knowledge of the control influence coefficients which lead to errors in the calculated feedback gains. (M.E.P.)

**A79-49235** - **Application of Lagrange Optimization to the drag polar utilizing experimental data.** J. A. Kohn (Grumman Aerospace Corp., Bethpage, N.Y.), *American Institute of Aeronautics and Astronautics, Aircraft Systems and Technology Meeting*, New York, N.Y., Aug. 20-22, 1979, Paper 79-1833, 15 p., 14 refs.

The Lagrange Optimization used with linear aerodynamic theory to define optimum aircraft geometry is shown to have application to the determination of optimum control surface deflections as a function of angle of attack necessary to provide maximum trimmed L/D for a multi-plane aircraft configuration. Linear aerodynamic theory suggests a semi-empirical drag polar equation well suited to the optimization task. The equation is shown to correlate well with experimental data near aircraft cruise conditions. Such correlations are shown for selected aft and forward swept configurations up to 0.9 Mach number both in terms of total drag and drag increments due to control deflections and angle of attack. Optimum trimmed configurations are defined using experimental data and the subject optimization procedure. (Author)

**A79-49832** - **Dynamics and control of large space structures - An overview.** S. M. Seltzer, *Journal of the Astronautical Sciences*, vol. 27, Apr.-June 1979, p. 95-101, 11 refs.

The paper presents a survey of the efforts being undertaken to solve the problem of dynamics and control of earth-orbiting spacecraft that are large flexible structures. Among these are the Defense Advanced Research Projects Agency (DARPA) Active Control of Space Structures (ACOSS), a development program in dynamic structural control which is being developed in several phases which involve industry and Truax Laboratory. Attention is also given to the approach taken by NASA and industry. This involves the Large Space Structures Technology (LSST) Program managed by Langley Research Center. In conclusion, seven critical areas which need more work are given. These are: (1) dynamic modeling, (2) control law development, i.e., digital techniques, (4) disturbance accommodation, (5) shape and/or figure control, (6) effector/actuator selection, and (7) innovation. (M.E.P.)

**A79-49833** - **Flexible spacecraft control by model error sensitivity suppression.** J. R. Sesak, T. Coradetti (General Dynamics Corp., Convair Div., San Diego, Calif.), and P. Likins (Columbia University, New York, N.Y.), *Journal of the Astronautical Sciences*, vol. 27, Apr.-June 1979, p. 131-156, 25 refs.

A model error sensitivity suppression method is presented to resolve sensitivity to modeling errors and limitations of flight computers, which permit only estimators of lower order than required to estimate all dynamically significant states together. A decentralized control concept results consisting of a collection of subsystems estimators and controllers, each independently charged with a subset of the system states. The key controller concept is the penalization in the performance index of any control action that excites modeled states other than those for which the subsystem control is charged, inhibiting control spillover. It is shown that performance indices can be modified to reduce control and observation spillover arbitrarily while preserving stability, and numerical examples are developed for the simply supported beam and an idealized space platform. (Author)

**A79-49834** - **Direct output feedback control of large space structures.** M. J. Balas (Bolt Beranek and Newman, Inc., Cambridge, Mass.), *Journal of the Astronautical Sciences*, vol. 27, Apr.-June 1979, p. 157-180, 35 refs.

Direct output feedback (DOFB) control of large structures in space (LSS) and the primary design trade-off of this method's root-mean-square modal control (RMMC) approach is presented. LSS are continuum structures requiring large dimensional models to predict their dynamic behavior, but the on-board computer capacity is limited so that active control of LSS is accomplished with a controller of smaller dimension than the dynamic structure model. This paper considers feedback control of  $N$  critical modes of a general LSS obtained by DOFB, i.e., sensor outputs are multiplied by a gain matrix to produce control actuator commands. The on-board computer capacity for DOFB is considerably lower than that for RMMC, which uses a state estimator to approximate the controlled mode state from the sensor outputs and applies control gains to the estimated state, but the number of control devices for DOFB to achieve the same control performance as RMMC is much higher. Both methods suffer from the effects of spillover due to the residual modes. (Author)

**A79-49835** - **On cost-sensitivity controller design methods for uncertain dynamic systems.** R. E. Skelton (Purdue University, West Lafayette, Ind.), *Journal of the Astronautical Sciences*, vol. 27, Apr.-June 1979, p. 181-205, 13 refs.

A 'two-model' theory of control design results when one chooses a high order 'evaluation model' to be used during simulations (evaluations) of the spacecraft system, and a low order 'controller design model' to be used during the analytical design of the control policy. Some limitations of the low order controller design model which are considered in this paper are: (1) calculations for the 'best' controller design model involve the control problem statement and the evaluation model; (2) the reduced order controller can move the poles of the evaluation model by an amount which is related to the order of the controller design model; (3) the optimum sensor and actuator locations also depend upon the order of the controller design model which is to be used; and (4) the 'best' controller design model may also be influenced by parameter sensitivity considerations. These considerations lead to a 'cost sensitivity' approach to modeling. (Author)

**A79-50033** - **Indirect adaptive stabilization of a large, flexible, spinning spacecraft - Simulation studies.** A. L. Hamer and C. R. Johnson, Jr. (Virginia Polytechnic Institute and State University, Blacksburg, Va.), in: *SOUTHEASTCON '79, Proceedings of the Region 3 Conference and Exhibit*, Roanoke, Va., April 1-4, 1979. New York, Institute of Electrical and Electronics Engineers, Inc., 1979, p. 53-56, 5 refs., Grant No. NCG 1527.

A recently formulated approach to the adaptive control of distributed systems combines the simultaneous identification and control philosophy of indirect adaptive control with a modal expansion description of distributed systems. The regulation of a large, flexible, spinning spacecraft, one half of a dual momentum control device proposed for attitude control of large space systems, provides the example upon which the capabilities of such a synthesis method are tested via simulation. (Author)

**A79-50463** - **Stabilization of the shape of a deploying surface (O stabilizatsii formy razmeshchivayemoy poverkhnosti).** V. I. Burakov, *Kosmicheskie Issledovaniya*, vol. 17, July-Aug. 1979, p. 547-558, 5 refs., in Russian.

The paper considers the problem of stabilizing the shape of the radio-reflective surface of a large space telescope. It is found that the use of an automatically deploying modular structure makes it possible to control the shape of the reflective surface without elastic deformations of the telescope elements. An iterative method for determining points of reference on the stabilized surface is presented. Control laws are derived for assuring the total stability of module



## 04 CONTROL SYSTEMS

points of reference for structures with sufficiently large focal distances. B.J.

**A79-53063** Assessment of the errors of an analytical method of calculating the geocentric trajectories of a solar sail (Otsenka pogreshnosti analiticheskogo metoda rascheta geotsentricheskikh traektorii apparata s solnechnym parusom). L. K. Grinevitskaya and E. N. Polukhova. *Leningradskii Universitet, Vestnik, Matematika, Mekhanika, Astronomiya*, Apr. 1979, p. 95-98. In Russian.

The capability of a solar sail to compensate for disturbances acting on it during space flights is examined. The approximate least-time control of the sail angle to provide transition from the initial to the terminal state is determined on the basis of Pontryagin's principle of maximum and a proposed averaging scheme. A programmed method for calculating the minimum time required for orbital corrections is proposed. V.P.

**A79-53362** Distributed control of two typical flexible structures. B. Goren and J. Broquet (Matra, S.A., Velizy Villacoublay, Yvelines, France). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-212*, 17 p.

Two studies of distributed and multiple control of flexible structures which deal with the control performance according to the sensing and actuating system location on the structure are presented. The first study examines the control of a satellite main body provided with a large flexible appendage with one degree of rotation controlled by a torque motor. Comparison is made of performance of the torque motor and of the internal main body actuator, or of both actuators according to sensing functions and locations, such as measurement of absolute motion of main body and relative motion between appendage and main body at torque motor level. The second study treats the active control of large structures built from rigid bodies connected through flexible hinges, and for one example of structure with limited number of elements the structural eigenfrequencies are determined and the modes shapes are shown. Finally, the optimum location of actuator to actively control the structure is discussed in terms of mode disturbance. A.T.

**A79-52945** Stability of proportional-plus-derivative-plus-integral control of flexible spacecraft. P. C. Hughes (Toronto, University, Downsview, Ontario, Canada) and T. M. Abdel Rahman (Spac Aerospace, Ltd., Toronto, Canada). *Journal of Guidance and Control*, vol. 2, Nov. Dec. 1979, p. 499-503, 15 refs. Natural Science and Engineering Research Council of Canada Grant No. A-4183.

The linear attitude control of flexible spacecraft is considered. The feedback law is of the proportional-plus-derivative-plus-integral class. The sensor and actuator dynamics are included, albeit in simple models. The structural flexibility model is unrestricted except for the usual assumption of small deflections. The principal result of the paper is that if the controller is unconditionally stable (with respect to gain), assuming the satellite to be rigid, then structural flexibility cannot destabilize it. This and other possibilities are illustrated by numerical examples. (Author)

**N79-22177\*** Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena. **POINTING AND CONTROL SYSTEM ENABLING TECHNOLOGY FOR FUTURE AUTOMATED SPACE MISSIONS**. J. B. Dahlgren. 30 Dec. 1978. 77 p. refs. (Contract NAS7-100) (NASA-CR-158513, JPL-PUB-79-23) Avail. NTIS HC A05/MF A01 CSCL 22B

Future automated space missions present challenging opportunities in the pointing-and-control technology disciplines. The enabling pointing-and-control system technologies for missions from 1985 to the year 2000 were identified and assessed

A generic mission set including Earth-orbiter, planetary, and other missions which predominantly drive the pointing-and-control requirements was selected for detailed evaluation. Technology candidates identified were prioritized as planning options for future NASA-OAST advanced development programs. The primary technology thrusts in each candidate program were cited, and advanced development programs in pointing-and-control were recommended for the FY 80 to FY 87 period, based on these technology thrusts. J.M.S.

**N79-25122\*** Howard Univ., Washington, D.C. School of Engineering. **THE DYNAMICS AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES. 2. PART A: SHAPE AND ORIENTATION CONTROL USING POINT ACTUATORS**. Final Report. Peter M. Barnum and A. S. S. R. Reddy. Jun. 1979. 78 p. refs. (Grant NSG 1414) (NASA-CR-158584) Avail. NTIS HC A05/MF A01 CSCL 22B

The equations of planar motion for a flexible beam in orbit which includes the effects of gravity gradient torques and control torques from point actuators located along the beam was developed. Two classes of theorems are applied to the linearized form of these equations to establish necessary conditions for controllability for preselected actuator configurations. The feedback gains are selected: (1) based on the decoupling of the original coordinates and to obtain proper damping, and (2) by applying the linear regulator problem to the individual modal coordinates separately. The linear control laws obtained using both techniques were evaluated by numerical integration of the nonlinear system equations. Numerical examples considering pitch and various number of modes with different combination of actuator numbers and locations are presented. The independent modal control concept used earlier with a discretized model of the thin beam in orbit was reviewed for the case where the number of actuators is less than the number of modes. Results indicate that although the system is controllable it is not stable about the nominal (local vertical) orientation when the control is based on modal decoupling. An alternate control law not based on modal decoupling ensures stability of all the modes. S.E.S.

**N79-27855\*** Astro Research Corp., Carpinteria, Calif. **STUDY OF MEMBRANE REFLECTOR TECHNOLOGY**. Final Report. Kari Knapp and John Hedgepeth. 2 Jan. 1979. 39 p. Sponsored by NASA. Prepared for JPL. (Contract JPL-955081) (NASA-CR-158729, ARC-TN-1071, JPL 9950 104) Avail. NTIS HC A03/MF A01 CSCL 10A

Very large reflective surfaces are required by future spacecraft for such purposes as solar energy collection, antenna surfaces, thermal control, attitude and orbit control with solar pressure, and solar sailing. The performance benefits in large membrane reflector systems, which may be derived from an advancement of this film and related structures technology, are identified and qualified. The results of the study are reported and summarized. Detailed technical discussions of various aspects of the study are included in several separate technical notes which are referenced. G.Y.

**N79-29215\*** Bendix Corp., Teterboro, N.J. Guidance Systems Div. **SPACE CONSTRUCTION BASE CONTROL SYSTEM**. Final Report. 27 Oct. 1978. 362 p. refs. (Contract NAS8-32660) (NASA-CR-161288) Avail. NTIS HC A16/MF A01

Aspects of an attitude control system were studied and developed for a large space base that is structurally flexible and

## 04 CONTROL SYSTEMS

whose mass properties change rather dramatically during its orbital lifetime. Topics of discussion include the following: (1) space base orbital pointing and maneuvering, (2) angular momentum sizing of actuators, (3) momentum desaturation selection and sizing, (4) multilevel control technique applied to configuration one, (5) one-dimensional model simulation, (6) N-body discrete coordinate simulation, (7) structural analysis math model formulation, and (8) discussion of control problems and control methods.

Author

**N79-29222** Howard Univ., Washington, D. C.

**THE DYNAMICS AND OPTIMAL CONTROL OF SPINNING SPACECRAFT WITH MOVABLE TELESCOPING APPENDAGES Ph.D. Thesis**

Ramasamy Gounder Sellappan 1977 178 p

Avail. Univ. Microfilms Order No. 7915942

Two types of telescoping appendages were considered: (1) where the end masses are mounted at the end of the assumed massless booms, and (2) where the appendages are assumed to consist of a uniformly distributed homogeneous mass throughout their lengths. For the telescoping system, Eulerian equations of motion were developed. Closed-form analytical solutions for the time response of the transverse components of angular velocity were obtained for the spacecraft hub with spherical and nearly spherical mass distribution. As an application to spacecraft rescue and recovery, booms were extended along all the principal axes to (1) detumble a symmetrical spacecraft, and (2) achieve a desired final spin about one of the principal axes.

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**05**  
**ELECTRONICS**

Includes techniques for power and data distribution

**N79-24441\*** National Aeronautics and Space Administration  
Marshall Space Flight Center, Huntsville, Ala

**A PROGRAMMABLE POWER PROCESSOR FOR A 25-kW  
POWER MODULE**

Roy Lanier, Jr., Robert E. Kapustka, and John R. Bush, Jr. Jan  
1979 23 p refs

(NASA-TM 78215) Avail NTIS HC A03/MF A01 CSCL  
10B

A discussion of the power processor for an electrical power system for a 25 kW Power Module that could support the Space Shuttle program during the 1980's and 1990's and which could be a stepping stone to future large space power systems is presented. Trades that led to the selection of a microprocessor controlled power processor are briefly discussed. Emphasis is given to the power processing equipment that uses a microprocessor to provide versatility that allows multiple use and to provide for future growth by reprogramming output voltage to a higher level (to 120 V from 30 V). Efficiency data from a breadboard programmable power processor are presented, and component selection and design considerations are also discussed. G Y

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## 06 ADVANCED MATERIALS

**Includes matrix composites, polyimide films and thermal control coatings, and space environmental effects on these materials.**

**A79-34754 \*** **A nonlinear stress-strain law for metallic meshes.** S. Tang, R. Boyle, J. Whiteside, and R. Anderson (Grumman Aerospace Corp., Bethpage, N.Y.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 459-466, 11 refs. (AIAA 79-0936)

Due to their high strength and light weight properties, use of flexible knitted mesh materials in current and future space-based antennas is increasing. In the present paper, a two-dimensional orthotropic nonlinear elastic stress-strain law is proposed for gold-coated triost metallic mesh material of diamond knit pattern. This constitutive relation accommodates geometrically nonlinear behavior due to the large displacement of the diamond shape cell as well as the nonlinear behavior due to the knitted configuration of the cell. Comparison with experimental data shows the proposed constitutive law provides a reasonably good description of the stress-strain behavior of this material. B.J.

**A79-36190 \*** **Effects of electron irradiation on large insulating surfaces used for European Communications Satellites.** J. Reddy and B. E. Serene (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands). (NASA and U.S. Air Force, Spacecraft Charging Technology Conference, Colorado Springs, Colo., Oct. 31-Nov. 2, 1978.) *ESA Journal*, vol. 3, no. 1, 1979, p. 41-47, 5 refs.

External configuration of the ESA's Orbital Test Satellite (OTS) and its derivatives ECS (European Communications Satellite) and Marecs (Maritime ECS) is such that the VHF shield assembly and the antenna dish are in contact with the space plasma and become charged electrostatically. Results of tests performed in a vacuum chamber show that although the charge reaches a reasonably high potential, the effects of discharges on material properties and electromagnetic interference are relatively insignificant for the antenna structure while for the VHF shield assembly the opposite is true. Considerable damage to the vacuum-deposited aluminum is observed. Associated with this are large transient currents that could severely affect the system electronics. With current external satellite design largely dictated by thermal (as well as handling and economic) requirements, a proper solution to this problem appears to be to provide the best possible desensitization of all susceptible circuitry. V.T.

**A79-43228** **The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Books 1 & 2.** Symposium sponsored by the Society for the Advancement of Material and Process Engineering, Azusa, Calif., Society for the Advancement of Material and Process Engineering (Science of Advanced Materials and Process Engineering Series, Volume 24, Book 1 and Book 2), 1979, Book 1, 858 p.; Book 2, 778 p. Price of two books, \$56.

The proceedings focus on developments in materials technology for energy and environmental problems of the 1980s. Particular consideration is given to nonterrestrial material processing and manufacturing of large space systems, sandwich constructions for aircraft and communications, materials for airline safety, thermal coatings for missile warhead fire protection, and satellite applications of metal matrix composites. Papers are also presented on polyimide/graphite, aluminum/SiC, and fiber reinforced titanium composites, pressure vessel steels for coal gasifiers, environmental effects of composite material processing, adhesive bonding of sandwich structures, heatshield materials for rocket launching systems, and the effects of particulates on solar cells. A.T.

**A79-43231 \*** **Graphite fiber reinforced glass matrix composites for aerospace applications.** K. M. Prewé, J. F. Bacon (United Technologies Research Center, East Hartford, Conn.), and D. L. Dicus (NASA, Langley Research Center, Materials Research Branch, Hampton, Va.). In: The enigma of the eighties: Environment, economics, energy. Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 1. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 61-71, 7 refs. Contract No. NAS1-14346

The graphite fiber reinforced glass matrix composite system is described. Although this composite is not yet a mature material, it possesses low density, attractive mechanical properties at elevated temperatures, and good environmental stability. Properties are reported for a borosilicate glass matrix unidirectionally reinforced with 60 volume percent HMS graphite fiber. The flexural strength and fatigue characteristics at room and elevated temperature, resistance to thermal cycling and continuous high temperature oxidation, and thermal expansion characteristics of the composite are reported. The properties of this new composite are compared to those of advanced resin and metal matrix composites showing that graphite fiber reinforced glass matrix composites are attractive for aerospace applications. (Author)

**A79-43302** **Moisture effects on spacecraft structures.** J. Hertz (General Dynamics Corp., Convair Div., San Diego, Calif.). In: The enigma of the eighties: Environment, economics, energy. Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 965-978

The various effects of moisture on graphite/epoxy composites are described with particular emphasis on the resultant changes in physical dimensions. Details are presented on material selection for space applications including material design allowables, outgassing, microcracking, and moisture effects. Absorption of moisture is described as a function of laminate thickness, ply orientation, relative humidity, and temperature. The weight gain as a function of time is correlated to change in length. Details are presented on desorption both at ambient pressure and in vacuum as a function of time and temperature. The use of metallic coatings for the sealing of composites against moisture absorption is described, and the effects of these coatings on overall composite coefficient of thermal expansion and weight are evaluated. (Author)

**A79-43305 \*** **Space radiation effects on composite matrix materials - Analytical approaches.** C. Giori (ITT Research Institute, Chicago, Ill.). In: The enigma of the eighties: Environment, economics, energy. Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1012-1020. Contract No. NAS1-15469

## 06 ADVANCED MATERIALS

In-vacuo ultraviolet and gamma radiation exposure tests are utilized in a study aimed at the identification of radiation damage mechanisms in composite materials, with the objective of predicting the long-term behavior of composite structures in a space environment at geosynchronous orbit. Physical and chemical methods of polymer characterization are utilized for the study of composite matrix degradation, in conjunction with GC-MS techniques for the analysis of volatile by products. (Author)

**A79-43306** Space radiation effects on spacecraft materials. G. L. Brown, J. F. Thomasson, and R. M. Kurland (TRW Defense and Space Systems Group, Redondo Beach, Calif.). In: The enigma of the eighties: Environment, economics, energy, Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1021-1031. Contract No. F04701 74-C-0562.

An experimental investigation is being conducted to determine changes in thermophysical and tensile properties of polymeric film materials and mechanical properties of certain composite systems when exposed to simulated combined elements of a synchronous equatorial orbit space environment. The materials examined are presently being used or have proposed application as external materials on long lifetime space systems. The facility used for testing permits sizeable quantities of test specimens to be exposed in vacuum to a combined simulation of the critical elements of the natural space environment and provides for in situ evaluation of the radiation effects. This paper briefly describes the testing facility and test procedures and presents key thermophysical and tensile test results. It is shown that some materials experience substantial changes in their properties due to radiation exposure. (Author)

**A79-43307** Materials evaluation for use in long-duration space missions. R. L. Long (Rockwell International Corp., Satellite Systems Div., Downey, Calif.). In: The enigma of the eighties: Environment, economics, energy, Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1032-1038. 7 refs.

Methods are outlined that have the potential of predicting the performance of untried, newly developed materials so these may be used to construct vehicles suitable for long-duration missions in known but variable space environments. One of the methods uses the concept of accelerated aging by intensifying space environment components and the limitations of this method are described. A second, more innovative method is based on the concept like materials perform in a similar manner and uses the real-time performance of proven materials to predict the performance of a new material containing like functional groups. (Author)

**A79-43321** Satellite applications of metal-matrix composites. H. H. Armstrong (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). In: The enigma of the eighties: Environment, economics, energy, Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1250-1264. 7 refs. Research supported by the Lockheed Independent Research and Development Program, Contract No. F33615-77-C-5190. ARPA Order 3411.

Studies concerning the application of metal-matrix composites in satellites, for which high stiffness, low expansion, high conductivity, and the absence of moisture absorption and outgassing may be requirements, show material systems composed of continuum-filament fibers in a metal matrix are particularly attractive. Graphite, boron, silicon/carbide, and aluminum/oxide fibers in a matrix of

aluminum or magnesium are compared to graphite-epoxy and conventional materials. The system effectiveness of graphite fibers in aluminum and magnesium is shown to be very good in satellite design applications in which thermal/structural distortion or high specific stiffness is a major consideration. Characterization of high modulus graphite fibers in aluminum metal-matrix materials to establish a reliable data base and use of these data in the design of space structures are discussed. (Author)

**A79-43322** The application of metal-matrix composites to spaceborne parabolic antennas. W. D. Wade and A. M. Ellison (Lockheed Missiles and Space Co., Inc., Space Systems Div., Sunnyvale, Calif.). In: The enigma of the eighties: Environment, economics, energy, Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1265-1275.

The application of graphite-reinforced metal composites is investigated for large deployable antennas. The performance of large parabolic reflectors is discussed, and the requirements for stiffness and precise surface accuracy are established. The wraprib style deployable antenna is described and special problems associated with the design are discussed. The design requirements considered include low thermal and structural distortion, dynamic response, rib stiffness and stability, and long term storage. These design requirements result in the need for materials having high specific stiffness, low thermal expansion, high thermal conductivity, good micro yield strength, low outgassing, and resistance to dimensional change resulting from moisture absorption. A point design of the wrap-rib antenna is used to compare performance with existing and projected materials. Materials considered include graphite-epoxy, graphite-aluminum, and graphite-magnesium. (Author)

**A79-43323** Thermally stable, thin, flexible graphite-fiber/aluminum sheet. R. F. Karlak (Lockheed Research Laboratories, Palo Alto, Calif.) and E. Willner (Lockheed Missiles and Space Co., Inc., Satellite System Div., Sunnyvale, Calif.). In: The enigma of the eighties: Environment, economics, energy, Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1276-1287. Research supported by the Lockheed Independent Research and Development Program, Contract No. F33615-77-C-5190.

Effective utilization of graphite-fiber/aluminum sheet's exceptional longitudinal properties, for furlable space antenna ribs, requires the simultaneous optimization of in-plane thermal properties and bending characteristics. This has been accomplished by a combination of alloy selection, fabrication parameters, and heat treatments. The flexural characteristics of the material are discussed in light of lamination theory and their mechanical properties of the core material and aluminum face sheets after aging and subsequent thermal processing to mitigate the detrimental influence of internal residual stresses that develop on cooling from the artificial aging temperature. (Author)

**A79-43330** Dimensional stability investigation Graphite/epoxy truss structure. R. L. Kulin (Martin Marietta Aerospace, Denver, Colo.) and G. E. Pynchon (Composite Optics, Inc., San Diego, Calif.). In: The enigma of the eighties: Environment, economics, energy, Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1356-1371.

The stability characteristics of a graphite/epoxy truss structure made of unidirectional tape and woven fabric are reported. Tube and

joint specimens were subjected to an evaluation of dimensional stability by thermal cycling to determine coefficients of thermal expansion (CTE), and to moisture exposure to measure dimensional strains due to changed moisture content. The CTE data indicate that the onset of microcracking is below -100 F for this composite system, and that between 100 F and +200 F the components are stable in terms of thermal expansion behavior. The humidity desorption data shows that drying from an equilibrium moisture content corresponding to 50% relative humidity will cause a longitudinal strain of 40 ppm in the tubes and 70 ppm in the joints. These values are dimensionally equivalent to the results of a temperature change of up to 200 F in the axial direction of the tubes and 90 F in the axial direction of the joints. A T.

**A79-46700** Materials degradation in space environments. M. R. Louthan, Jr., R. P. McNitt, and R. D. Sison (Virginia Polytechnic Institute and State University, Blacksburg, Va.). *American Institute of Aeronautics and Astronautics. Fluid and Plasma Dynamics Conference*. 7th, Williamsburg, Va., July 23-25, 1979. Paper 79-1508. 6 p. 28 refs.

Three characteristics of space environments—high radiation levels, vacuum, and extreme temperatures—must be considered in relation to in-flight materials degradation. Design criteria which provide totally satisfactory ground-based performance may be inadequate for space. In the present paper selected degradation problems are discussed with emphasis on the adverse effects of radiation on semiconductor devices, the effects of extreme temperatures on the impact properties of metallic and nonmetallic structural members and the effects of vacuum on the fatigue and wear of working components. B.J.

**N79-24036\*** European Space Agency, Paris (France). **EFFECTS OF ELECTRON IRRADIATION ON LARGE INSULATING SURFACES USED FOR EUROPEAN COMMUNICATIONS SATELLITES**. J. Reddy and B. E. H. Serene. In NASA. Lewis Res. Center. *Spacecraft Charging Technol.* 1978. 1979 p. 570-586 refs.

Avail NTIS HC A99/MF A01 CSCL 22B

Samples of aluminized Kapton used for passive thermal control on the VHF shield and the antenna dish of ESA's OTS satellite and its derivatives were subjected to an incident electron beam of 25 keV and irradiated for 8 hours at room temperature and at -173 C under a vacuum of the 10 to the minus 6 th power torr. Visual observations during electron irradiation, measurements of leakage current and discharge characteristics, and material degradation following completion of irradiation are discussed. A.R.H.

**N79-30297\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va. **GRAPHITE/POLYIMIDE COMPOSITES**. H. Benson Dexter, ed. and John G. Davis, Jr., ed. Aug 1979. 449 p. refs. Proc. held at Hampton, Va., 28 Feb.-1 Mar. 1979. (NASA-CP-2079, L-12953). Avail NTIS HC A19/MF A01 CSCL 11D.

Technology developed under the Composites for Advanced Space Transportation System Project is reported. Specific topics covered include fabrication, adhesives, test methods, structural integrity, design and analysis, advanced technology developments, high temperature polymer research, and the state of the art of graphite/polyimide composites.

**N79-30304\*** Rockwell International Corp., Downey, Calif. **FABRICATION OF STRUCTURAL ELEMENTS**. Fred J. Darms, Jr. In NASA. Langley Res. Center. *Graphite/*

*Polyimide Composites*. Aug 1979. p. 111-122.

(Contract NAS1-15183).

Avail NTIS HC A19/MF A01 CSCL 11D.

The laminate fabrication procedures and quality assurance ultrasonic C-scan results used for structural elements are described. These procedures are the result of processing eleven lots of graphite/PMR-15 prepreg tape materials and two lots of graphite/NR-150B2. Early processing difficulties with NR-150B2 composites were corrected, permitting the fabrication of quality specimens from either of the two currently prescribed matrix materials. The quality of all deliverable specimens is measured by the control of fiber content, glass transition temperature, and void content, as well as laminate ultrasonic C-scan data. J.M.S.

**N79-30328\*** McDonnell Douglas Astronautics Co., Huntington Beach, Calif. **GRAPHITE/POLYIMIDES STATE OF THE ART PANEL DISCUSSION**. Robert C. Curley. In NASA. Langley Res. Center. *Graphite/Polyimide Composites*. Aug 1979. p. 445-450.

Avail NTIS HC A19/MF A01 CSCL 11D.

A brief overview of current and planned applications of graphite/polyimide composites is presented. A short discussion of technical problems delaying the application of graphite/polyimide composites in aerospace structures and near-term solutions to these problems are also included. Author.

**N79-30737\*** AEG-Telefunken, Wedel (West Germany). **NEW FLEXIBLE SUBSTRATES WITH ANTI-CHARGING LAYERS FOR ADVANCED LIGHTWEIGHT SOLAR ARRAYS**. D. Ruesch. In ESA. *Photovoltaic Generators in Space*. Nov 1978. p. 41-48. refs. Sponsored by Bundesmin. fuer Forsch. u. Technol.

Avail NTIS HC A15/MF A01.

Increasing power demands for future space missions has stimulated the development of large area flexible solar arrays. Several flexible substrates for application to large area flexible solar arrays according to mission requirements were developed. Various methods for providing a rear-side anti-charging layer were also developed. The mechanical and physical properties of glass fiber, carbon fiber, and aramid fiber reinforced Kapton substrates are presented. Fabrication processes are described. Recommendations are given for suitable applications of the various substrate types in space solar arrays. Author (ESA).



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## ASSEMBLY CONCEPTS

**Includes automated manipulator techniques, EVA, robot assembly, teleoperators, and equipment installation.**

**A79-34731** \* **Space manipulators - Present capability and future potential.** J. D. Graham, R. Ravindran (Spar Aerospace, Ltd., Toronto, Canada), and K. Knapp (Astro Research Corp., Carpinteria, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 243-253. (AIAA 79-0903)

The various tasks manipulators will perform in space to the year 2000 are discussed. Emphasis in the paper is placed on the development of the Shuttle Remote Manipulator System (SRMS), with a description presented of the overall system and the component subsystems. Potential modifications to the SRMS are discussed together with the expected increased capability and performance. Future requirements for other types of manipulators are also discussed together with likely required design features. **B.J.**

**A79-34757** \* **Large space system automated assembly technique.** P. Stryk (General Dynamics Corp., Convair Div., San Diego, Calif.) and D. A. Kugath (General Electric Co., Space Div., Philadelphia, Pa.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 481-492. (AIAA 79-0939)

A concept (LSAT) has been developed for compatibly designing a truss frame space structure and an assembler that assembles and maintains the structure plus its subsystems, lines, and working surfaces. Use is made in this concept of programmed assembly, maintenance, and repair processes based on similar state-of-the-art industrial automated processes. The structure is progressively constructed by the assembler which is carried through the structure at a constant velocity by means of belt transports that engage the structure at its nodes. An assembler consists of two-crawlers joined by an articulated coupling. The forward crawler carries stacks of struts and nodes and assembler arms that assemble the structure. The rear crawler houses most of the control, spares, power, and communication subsystems, and is essential for the truss junction construction process. **(Author)**

**A79-34982** \* **Advanced teleoperators.** A. K. Bejczy (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *Astronautics and Aeronautics*, vol. 17, May 1979, p. 20-31. 33 refs. Contract No. NAS7-100.

Advanced teleoperators are discussed, with emphasis on the remote manipulation system designed to perform such actions as grasping, orienting, moving, placing, and inserting objects. Geometrical performance dimensions are considered, indicating that a manipulator is limited to three-orders-of-magnitude ratio of workspace extension to positioning accuracy. The control system is examined, showing that a manipulative task requires coordination of several joints, with the relationship between the task definers and the joint variables given by complex trigonometrical transformations. Control modes developed in the last 20 years are noted, including program controlled industrial 'robots' which can endlessly repeat a fixed sequence of motions without operator intervention, and the sensor-referenced/computer-controlled mode manipulators. Advanced proximity sensor systems are taken into account, with emphasis on the applications of the force-torque and slip models. The proximity sensor system for the shuttle-size manipulator is described. **A.A.**

**A79-34985** \* **Construction in space - Toward a fresh definition of the man/machine relation.** H. H. Watters and J. W. Stokes (NASA, Marshall Space Flight Center, Huntsville, Ala.). *Astronautics and Aeronautics*, vol. 17, May 1979, p. 42-45, 63.

The EVA (extravehicular activity) project forming part of the space construction process is reviewed. The manual EVA construction, demonstrated by the crew of Skylab 3 by assembling a modest space structure in the form of the twin-pole sunshade, is considered, indicating that the experiment dispelled many doubts about man's ability to execute routine and contingency EVA operations. Tests demonstrating the feasibility of remote teleoperator rendezvous, station keeping, and docking operations, using hand controllers for direct input and television for feedback, are noted. Future plans for designing space construction machines are mentioned. **A.A.**

**A79-40529** **Teleoperator system for management of satellite deployment and retrieval.** J. R. Truett and R. A. Spencer (Martin Marietta Aerospace, Denver, Colo.). In: NTC '78, National Telecommunications Conference, Birmingham, Ala., December 3-6, 1978, Conference Record, Volume 1. Piscataway, N.J., Institute of Electrical and Electronics Engineers, Inc., 1978, p. 16.5.1-16.5.4.

A Teleoperator Retrieval System (TRS) is now being developed. This system, a remotely controlled maneuverable spacecraft, is briefly described. While the TRS will initially be used in the Skylab boost mission, the emphasis of this paper is on the future applications envisioned for the vehicle and its derivatives. The operational availability of the TRS to perform satellite deployment, satellite retrieval, and on-orbit servicing allows spacecraft designers and mission planners significant flexibility and new approaches to low-cost design. **(Author)**

**A79-47201** \* **On-orbit assembly of Large Space Structures (LSS) using an autonomous rendezvous and docking.** F. A. Vandenberg (Martin Marietta Aerospace, Denver, Colo.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Provincetown, Mass., June 25-27, 1979, AAS Paper 79-100*, 18 p.

The paper describes how Large Space Structures (LSS) components will accomplish autonomous rendezvous and docking, a capability which will be needed more frequently in the Space Shuttle era. It is shown that a nearly optimum rendezvous (in respect to propellant consumption) between the vehicles in nearly circular and coplanar orbits can be accomplished by using parabolic control curves in it proportional navigation algorithm. Finally, a method of accomplishing an optimum autonomous rendezvous is presented, that does not need complex orbital equations of the vehicles' states to execute a Hohmann transfer type of rendezvous. **M.E.P.**

**A79-53421** \* **Manned remote work station - Safety and rescue considerations.** C. A. Nathan (Grumman Aerospace Corp., Bethpage, N.Y.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-A-19*, 20 p. 10 refs. Contract No. NASg-15581.

It is noted that due to restrictions of payload and volume limitations of current and projected launch systems, space construction of ultralarge space structures is essential. The present paper discusses the concepts of a key piece of construction equipment needed to support assembly of such large structures. Attention is given to the manned remote work station (MRWS), a universal crew cabin to be used as a construction cherry picker, space crane turret, work station on a construction base rail system, or a free flyer. Concepts and safety and rescue requirements for this spacecraft are delineated for early applications in support of Shuttle operations, as well as applications in support of a mid to late 1980's space construction base. Finally, applications in support of constructing and maintaining a solar power satellite system are covered. **M.E.P.**

## 07 ASSEMBLY CONCEPTS

**N79 22562\*** Lockheed Missiles and Space Co., Sunnyvale, Calif.

### **AUTOMATIC IN-ORBIT ASSEMBLY OF LARGE SPACE STRUCTURES**

Georges G. Jacquemin. In NASA. Johnson Space Center. The 13th Aerospace Mech. Symp. 1979. p. 283-291. refs.

Avail. NTIS HC A13/MF A01 CSCL 22A

The automated assembly of a large number of components required for the on-orbit erection of large tetrahedral space platforms is described. The assembly machine is a huge jig in which a multitude of mechanisms must operate continuously in the thermo vacuum environment of space and under the control of computers programmed to command every step of each motion. The concepts are presented to determine the most reliable solution. Continuous operation of mechanisms in space presents many unresolved problems, with regard to lubrication of unprotected devices, such as chain drives, which must maintain reasonable positioning tolerances.

SEE

**N79 28201\*** Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena

### **AUTONOMOUS MECHANICAL ASSEMBLY ON THE SPACE SHUTTLE: AN OVERVIEW**

M. H. Raibert. 15 Jul 1979. 34 p. refs.

(Contract NAS7-100)

(NASA CR-158818 JPL PUB-79-62)

Avail. NTIS

HC A03/MF A01 CSCL 22A

The space shuttle will be equipped with a pair of 50 ft manipulators used to handle payloads and to perform mechanical assembly operations. Although current plans call for these manipulators to be operated by a human teleoperator, the possibility of using results from robotics and machine intelligence to automate this shuttle assembly system was investigated. The major components of an autonomous mechanical assembly system are examined, along with the technology base upon which they depend. The state of the art in advanced automation is also assessed.

A R H

## 08 PROPULSION

**Includes propulsion designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts.**

**A79-34704 \*** **Space propulsion technology overview.** J. J. Pelouch, Jr. (NASA, Lewis Research Center, Propulsion Systems Section, Cleveland, Ohio). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 24-29. (AIAA 79-0860)

This paper discusses Shuttle-era, chemical and electric propulsion technologies for operations beyond the Shuttle's orbit with focus on future mission needs and economic effectiveness. The adequacy of the existing propulsion state-of-the-art, barriers to its utilization, benefit of technology advances, and the prognosis for advancement are the themes of the discussion. Low thrust propulsion for large space systems is cited as a new technology with particularly high benefit. It is concluded that the Shuttle's presence for at least two decades is a legitimate basis for new propulsion technology, but that this technology must be predicated on an awareness of mission requirements, economic factors, influences of other technologies, and real constraints on its utilization. (Author)

**A79-34716 \*** **Orbit transfer vehicle propulsion for transfer of Shuttle-deployed large spacecraft to geosynchronous orbit.** W. J. Ketchum (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 123-127. 5 refs. (AIAA 79-0880)

An optimization methodology has been developed for Shuttle upper stage propulsion systems that will transfer a new generation of large spacecraft structures to geosynchronous orbit. The payload and Orbit Transfer Vehicle (OTV) comprise a single Shuttle flight for maximum utilization of the Shuttle, emphasizing a short length, high-performance OTV. This analysis evaluates the size and weight of the expanded structure and the performance of the OTV as a function of thrust-to-weight ratio and includes optimization of low-thrust trajectories to maximize structure size and determine optimum engine thrust level. Results presented indicate significant improvement using a low-thrust capability (less than 3 k) liquid O<sub>2</sub>/H<sub>2</sub> engine, and compare fixed thrust and throttled engines as well as solid motors (IUS) and a solar electric propulsion stage (SEPS). (Author)

**A79-34718 \*** **Inductive energy storage for MPD thrusters.** L. K. Rudolph and R. M. Jones (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 136-145. 14 refs. Contract No. NAS7-100. (AIAA 79-0883)

The high thrust density of the self field magnetoplasma dynamic (MPD) thruster makes it a promising candidate for many advanced space missions. The high power requirements of this thruster lead to

its operation in a pulsed mode from an energy storage device. The system characteristics of an inductive energy storage circuit with a solar array power from 25 kwe to 400 kwe are considered, by solving the circuit equations for the inductor charge and discharge phases. Using simple analytic models of the circuit components, the total system efficiency and inductance are determined as functions of the array output power and circuit resistance. The total system efficiency increases with array power and is acceptable (0.7) for low values of circuit resistance, indicating that superconducting circuitry may be desirable. The optimum charge-discharge cycle changes fundamentally as the circuit resistance is decreased through a critical value dependent on the thruster operating characteristics. (Author)

**A79-34735 \*** **Planetary mission requirements, technology and design considerations for a solar electric propulsion stage.** M. J. Cork, R. C. Hestrup, W. A. Menard, and R. N. Olson (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 279-289. 8 refs. Contract No. NAS7-100. (AIAA 79-0908)

High energy planetary missions such as comet rendezvous, Saturn orbiter and asteroid rendezvous require development of a Solar Electric Propulsion Stage (SEPS) for augmentation of the Shuttle IUS. Performance and functional requirements placed on the SEPS are presented. These requirements will be used in evolution of the SEPS design, which must be highly compatible with both the spacecraft and the mission design. Previous design studies have identified critical SEPS technology areas and some specific design solutions which are also presented in the paper. (Author)

**A79-34738 \*** **Solar thermoelectric power generation for Mercury orbiter missions.** M. Sawallig (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.) and V. Raag (Synco Corp., Sunnyvale, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 306-314. 8 refs. Contract No. NAS7-100. (AIAA 79-0915)

Mercury orbiter mission study results have shown that conventional silicon solar cell array technology is not adequate to produce power because of expected temperatures which range from 90 C to +285 C in about 50 minutes for 16 sun eclipses/day. The solar thermoelectric generator (STG), which requires relatively high temperatures, is being developed as a replacement power source. Several thermoelectric technologies (i.e., lead telluride alloys, bismuth telluride, silicide, and silicon-germanium alloys) have been examined for their suitability. Solar concentrator configurations (i.e., flat plate, Fresnel lens, mini-cone, and Cassegrain types) were also studied as candidates for increasing incident radiation during Mercury orbital operations. Detailed results are presented, and show that an STG design based on the use of silicon-germanium alloy thermoelectric material and using high-voltage thermopiles with individual miniconcentrators presents the optimum combination of technology and configuration for minimizing power source mass. (Author)

**A79-34772 \*** **Is a versatile orbit transfer stage feasible.** D. A. Heald (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 594-599. 11 refs. (AIAA 79-0866)

Orbital Transfer Vehicle (OTV) concepts include modular, all-propulsive, and aeromaneuvering configurations. Engine candidates include expander or staged combustion cycles which are throttleable from 20K pounds thrust and multiple installations of

## ON PROPULSION

new technology engines in the 3K range. The test direction of OTV development may be an evolutionary program starting with Centaur, growing to larger reusable systems, and ultimately using aerodynamic braking to return to the Orbiter or to earth. S.J.

**A79-34774 \*** **Increased capabilities of the 30-cm diameter Hg ion thruster.** V. K. Rastlin and C. E. Hawkins (NASA, Lewis Research Center, Cleveland, Ohio). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers, New York, American Institute of Aeronautics and Astronautics, Inc., 1979, 20 p. 21 refs. (AIAA 79-0910)

A 30-cm-diam mercury ion thruster, using two or three grid ion accelerating systems, is operated at increased values of beam current. Comparisons with the SEP (Solar Electric Propulsion) and EPSEP (Extended Performance SEP) baseline thrusters are made with respect to performance and lifetime. It is found that when a third, or decelerator, grid is added to the conventional two-grid optics of a SEP-like thruster, the ion beam focusing properties are improved, as expected from theoretical considerations. The total thruster efficiency as a function of specific impulse, is increased for values of specific impulse in the range 1200-2800 sec. Lifetime test results predict a thruster lifetime, under space conditions, not less than that of the baseline SEP thruster. S.D.

**A79-34847 \*** **High performance solar sails and related reflecting devices.** K. E. Drexler, Princeton University and American Institute of Aeronautics and Astronautics. Conference on Space Manufacturing Facilities, 4th, Princeton University, Princeton, N.J., May 14-17, 1979, AIAA Paper 79-1418 8 p. 6 refs. NSF supported research.

High performance solar sails are light tension structures bearing space-manufactured, thin film reflecting elements. They offer thrust to mass ratios 20 to 80 times those of proposed deployable sails. Development costs and risks appear modest. The low cost expected for sail production promises to make these sails more cost effective than solar electric propulsion for most missions of interest. Applications to near-earth orbital transfers, deep space scientific missions (some unique), and nonterrestrial resource recovery are examined and found attractive. In the latter application, sails permit recovery of asteroidal resources with a very low initial investment. The promise of high performance, low cost, and great versatility recommend this system for further study. (Author)

**A79-39815 \*** **Low thrust chemical orbit transfer propulsion.** J. J. Felboudh, Jr. (NASA, Lewis Research Center, Space Propulsion and Power Div., Cleveland, Ohio). AIAA, SAE, and ASME Joint Propulsion Conference, 15th, Las Vegas, Nev., June 18-20, 1979, AIAA Paper 79-1182, 20 p.

The need for large structures in high orbit is discussed in terms of the many mission opportunities which require such structures. Mission and transportation options for large structures are presented, and it is shown that low-thrust propulsion is an enabling requirement for some missions and greatly enhancing to many others. A general comparison of electric and low-thrust chemical propulsion is made and the need for and requirements of low-thrust chemical propulsion are discussed in terms of the interactions that are perceived to exist between the propulsion system and the large structure. (Author)

**A79-47204 \*** **The inclination change for solar sails and low earth orbit.** T. O. Morgan (United Technologies Corp., Chemical Systems Div., Sunnyvale, Calif.). American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Provincetown, Mass., June 25-27, 1979, AAS Paper 79-104, 17 p.

A solar sail has been developed as a Space Shuttle Small Self-Contained Payload Unit in order to demonstrate the thrust

obtainable from solar radiation pressure. In this paper, the change in orbital inclination expected to result from the thrust of the solar sail in a minimum drag configuration in low earth orbit is calculated. A two-variable asymptotic expansion method is employed to solve the orbital equations of motion of a 10,000-sq ft solar sail for modes of sail orientation including variable and fixed roll angles around the instantaneous velocity vector. Results show that for a typical launch date an inclination change of 1.5 deg over the 60-day orbital lifetime of the mission can be achieved, with a change of 2.5 deg expected for a launch when the sun-earth system is in the optimal configuration. Little performance gain is noted for an active roll control mode over a fixed optimal mean roll angle. A.L.W.

**A79-51904 \*** **SEP solar array development testing.** R. V. Elms, Jr. (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.) and L. E. Young (NASA, Marshall Space Flight Center, Huntsville, Ala.). In: Intersociety Energy Conversion Engineering Conference, 14th, Boston, Mass., August 5-10, 1979, Proceedings, Volume 2, Washington, D.C., American Chemical Society, 1979, p. 1273-1277. Contract No. NAS8-31352.

This paper describes the test program of a lightweight 25 kW solar array for solar electric propulsion. A full-scale development wing was made of aluminum with the containment box cover of graphite-epoxy, while the flight design array wing uses a graphite-epoxy structure. The full-scale continuous long-term array extension must was tested for performance on a water table, and the full scale wing was functionally tested to demonstrate automatic containment box unlatching, wing extension, and retraction, blanket tensioning, and automatic application of blanket preload. The wing was then tested to the Shuttle acoustic environment, followed by a thermal/vacuum test in which the wing was extended and retracted at high and low temperature. Finally, the wing was tested in vibration with sine and random vibration environments. A.T.

**A79-53258 \*** **Payload capacity of Ariane launched geostationary satellites using an electric propulsion system for orbit raising.** G. Krulle (Deutsche Forschungs und Versuchsanstalt für Luft und Raumfahrt, Stuttgart, West Germany). International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-32, 22 p. 37 refs.

The status of electric propulsion (EP) development, orbit raising strategies, assessed payload requirements, and comparisons of geostationary spacecraft with a solar electric propulsion system (SEPS) used with the West German radio frequency ion thruster RIT-25 electric propulsion system is presented. The RIT-10 system being qualified as an electric north-south keeping system in TV Sat and the larger RIT-25 primary propulsion system being developed are described, noting that advantages of using electric primary propulsion (EPs) are transfer missions, station keeping, and attitude and shape control on large satellites. The principal orbit raising strategies using EP, solar cell degradation, electrically raised Ariane spacecraft concepts, and the electrically propelled TV satellite configuration, propulsion system, solar generator, and mission characteristics are discussed. It was concluded that the most promising concept of electrically raised spacecraft appears to be the electrically propelled TV satellite extrapolated from TV Sat. A.T.

**N79-22190\*** **National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio**

### PRIMARY ELECTRIC PROPULSION FOR FUTURE SPACE MISSIONS

David C. Byers, Fred F. Torden, and Ira T. Myers. 1979. 45 p. refs. Presented at the Conf. on Adv. Technol. for Future Space Systems, Langley, Va., 8-11 May 1979, sponsored in part by AIAA.

(NASA-TM-79141, E-9994) Avail. NTIS HC AD3/MF AD1 CSCI 20C

A general methodology is presented which allows prediction of the overall characteristics of thrust systems employing electron-bombardment ion thrusters. Elements of the thrust system are defined and their characteristics presented in a parametric fashion. Two system approaches are evaluated where power management and control elements and thruster characteristics were substantially different. For an assumed system approach, the methodology presented predicts overall system properties, such as input power and mass, when major mission and thrust system parameters, such as trip time and specific impulse, are assumed.

Author

The need for large structures in high orbit is reported in terms of the many mission opportunities which require such structures. Mission and transportation options for large structures are presented, and it is shown that low-thrust propulsion is an enabling requirement for some missions and greatly enhancing to many others. Electric and low-thrust chemical propulsion are compared, and the need for an requirements of low thrust chemical propulsion are discussed in terms of the interactions that are perceived to exist between the propulsion system and the large structure.

SEE

**N79-23134/** Aerospace Corp., El Segundo, Calif. Ivan A. Getting Lab.

**MAGNETOSPHERIC AND IONOSPHERIC IMPACT OF LARGE-SCALE SPACE TRANSPORTATION WITH ION ENGINES** Interim Report

Yam T. Chiu, Janet G. Luhmann, Barbara K. Ching, Michael Schultz, and Donald J. Boucher, Jr. Dec. 1978 45 p refs (Contract F04700-78-M-2539) (AD-A065482, TR-0079(4960-04)-3; SAMSO-TR-79-3) Avail NTIS HC A03/MF A01 CSCL 21/3

Future large-scale space missions with payloads of - or - 10 million Kg (- or - 10,000 tons), such as the proposed Solar Power Satellite and Space Colonization, will probably require deep-space transportation systems based on the high specific-impulse ion engine. We note in this paper that the ion exhaust emissions corresponding to the proposed large payloads required for such missions may introduce basic modifications in the composition and dynamics of the ionosphere and magnetosphere. We identify some effects that such modifications may induce upon other space systems such as earth sensors, radiation belt dosage environment and signal scintillation due to beam-plasma interactions. We find that, because the space environment is tenuous, there is an interaction of sorts among such large-scale space systems and other earth-oriented space systems. The architectural design of such large-scale systems must take into account not only the efficient functioning of their primary mission objectives but also their influence upon the operations of other space systems.

Author (GRA)

**N79-24029\*** Boeing Aerospace Co., Seattle, Wash.

**PLASMA PARTICLE TRAJECTORIES AROUND SPACECRAFT PROPELLED BY ION THRUSTERS**

H. B. Lemmon, R. L. Copeland, and W. M. Laevens. In NASA Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 419-436 refs. Avail NTIS HC A99/MF A01 CSCL 228

The thruster plasma is assumed to be described by a collimated energetic beam and a cloud of ionized thermal propellant produced by charge-exchange. A simple adiabatic model is used to describe the expansion of these neutral plasmas away from the source. As the pressure falls, shielding currents dissipate, and the geomagnetic field takes control of the particles. In low earth orbit, it is concluded that the vehicle easily outruns its thruster plasma. At geosynchronous altitude, the local electric fields around high voltage surfaces collect return current from the thermal plasma that appears to be limited only by the available space charge. Results appropriate to proposed electric propulsion missions and the solar power satellite are presented and operational considerations are discussed.

Author

**N79-25129\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

**LOW THRUST CHEMICAL ORBIT TRANSFER PROPULSION**

J. J. Pelouch, Jr. 1979 22 p refs. Presented at the 15th Joint Propulsion Conf., Las Vegas, Nev., 18-20 Jun 1979, sponsored by AIAA, Soc. of Automotive Engrs., and ASME (NASA-TM-79190, E-059) Avail NTIS HC A02/MF A01 CSCL 228



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## 09

### FLIGHT EXPERMENTS

Includes controlled experiments requiring high vacuum and zero G environment.

A79-38053 \* *u* LDEF transverse flat plate heat pipe experiment /51005/. G. A. Robinson, Jr. (NASA, Marshall Space Flight Center, Huntsville, Ala.). *American Institute of Aeronautics and Astronautics, Thermophysics Conference, 14th, Orlando, Fla., June 4-6, 1979, Paper 79-1077*. 7 p. Contract No. NAS8-31847.

The paper describes the Transverse Flat Plate Heat Pipe Experiment. A transverse flat plate heat pipe is a thermal control device that serves the dual function of temperature control and mounting base for electronic equipment. In its ultimate application, the pipe would be a lightweight structure member that could be configured in a platform or enclosure and provide temperature control for large space structures, flight experiments, equipment, etc. The objective of the LDEF flight experiment is to evaluate the zero g performance of a number of transverse flat plate heat pipe modules. Performance will include: (1) the pipes transport capability, (2) temperature drop, and (3) ability to maintain temperature over varying duty cycles and environments. Performance degradation, if any, will be monitored over the length of the LDEF mission. This information is necessary if heat pipes are to be considered for system designs where they offer benefits not available with other thermal control techniques, such as minimum weight penalty, long-life heat pipe/structural members. (Author)

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# SOLAR POWER SATELLITE SYSTEM

Includes solar power satellite concepts with emphasis upon structures, materials, and controls

**A79-21265** " **An evolutionary solar power satellite program.** G. M. Hanley and W. R. Rhote (Rockwell International Corp., Satellite Systems Div., Downey, Calif.). *American Astronautical Society, Anniversary Conference, 25th, Houston, Tex., Oct. 30-Nov. 2, 1978, Paper 78-153*, 19 p.

An evolutionary solar power satellite (SPS) development plan was prepared to satisfy stated objectives. In this paper, effort is mainly directed to amplification of the technology advancement phase of the SPS development plan for the projected time frame 1980-1990. The discussion focuses on the microwave exploratory research program, the SPS power conversion/distribution and structures technology, the SPS orbital test platform evolution at low earth orbit and geosynchronous earth orbit, and the pilot plant demonstration phase. A well-focused ground test program supported by key Shuttle sortie experiments during the period 1980-1985 can lead to the evolution of the SPS orbital test platform during the latter part of the decade. Completion of the SPS technology advancement phase of SPS development in 1990 will provide the technical confidence to proceed with the full-scale pilot plant demonstration phase. S.D.

**A79-21266** " **A development strategy for the solar power satellite.** D. L. Gregory (Boeing Aerospace Co., Seattle, Wash.). *American Astronautical Society, Anniversary Conference, 25th, Houston, Tex., Oct. 30-Nov. 2, 1978, Paper 78-154*, 26 p.

An interdisciplinary study examined several problems associated with the solar power satellite (SPS) project, and the number of primary individual shuttle flights required to test the SPS concept is considered. It is suggested that a single sortie for launching a single large aperture satellite should be sufficient for providing proof of SPS concepts. The satellite and its role in studying developmental operations are described. After this project, which could be organized by about 1983, a later project, designed to assure success of major flight projects, would involve three shuttle flight sorties to study a structural beam 'machine', an orbital work station, and high power elements. M.L.

**A79-31908** **Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978.** Conference sponsored by the Royal Aeronautical Society and American Institute of Aeronautics and Astronautics. London, Royal Aeronautical Society, 1979. 336 p. \$35.

The energy research and development program of the U.S. is considered along with aspects of energy research and development on the basis of a UK view, prospects for reducing the fuel consumption of civil aircraft, the NASA aircraft energy efficiency program, aviation fuel from coal, commercial transports in the 1980s, the impact of aeronautical sciences on other modes of transport, and oil exploration from space. Attention is also given to the design and application of large wind turbine generators, off-shore multi-MW wind turbine system development as key to cost-effective wind energy for Sweden, a review of some critical aspects of satellite power systems, a preliminary assessment of the environmental impact of satellite power systems, European aspects of solar satellite power systems, and photovoltaics and solar thermal power systems. G.R.

**A79-31919** " **Status of the SPS concept development and evaluation program.** F. A. Koomanoff (U.S. Department of Energy, Satellite Power Systems Projects Office, Washington, D.C.). In: *Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978*. London, Royal Aeronautical Society, 1979. 17 p.

The Satellite Power System (SPS) is designed to capture solar radiation in geosynchronous orbit and, by means of photovoltaics, convert the solar energy to electrical energy. The current status of the SPS program is discussed by describing the systems definition activities, environmental and societal assessment activities, and the comparative assessment directions. The organization and funding for these activities are also presented. It is concluded that to date no program stoppers have been found, however, many significant questions remain unanswered, questions which must be answered before the next steps may be reached in determining if SPS is indeed an energy option for mankind. G.R.

**A79-31920** " **Solar Power Satellite systems definition.** G. R. Woodcock (Boeing Aerospace Co., Seattle, Wash.). In: *Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978*. London, Royal Aeronautical Society, 1979. 47 p.

A summary is provided of the results obtained in a detailed investigation of the technical and cost feasibility of Solar Power Satellites (SPS). Attention is given to SPS configuration options, the photovoltaic energy conversion, a recommended gallium arsenide satellite concept, the radiation degradation of solar cells, questions of power distribution, microwave power transmission, microwave generation technology, phase control, the power receiver system, ground-based power processing technology, laser power transmission, space transportation to low earth orbit, space-based construction and transportation operations, costing methods, cost analysis methodology, SPS cost ranges, economic analyses, resources requirements, and aspects of development and implementation. G.R.

**A79-31921** " **A review of some critical aspects of satellite power systems.** I. V. Franklin (British Aerospace, Dynamics Group, Weybridge, Surrey, England) and A. W. Rudge (Electrical Research Association, Ltd., RF Technology Centre, Leatherhead, Surrey, England). In: *Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978*. London, Royal Aeronautical Society, 1979. 18 p. 13 refs.

Some critical aspects of the Solar Power Satellite (SPS) are considered. The basic concepts of the SPS are considered along with aspects of SPS delivery and construction systems, solar arrays, on board electrical power collection, costs, European activities, and questions of development strategy. The SPS microwave system is examined, taking into account basic operations and constraints, the baseline microwave system, major areas of uncertainty, and the space antenna. G.R.

**A79-31923** " **European aspects of Solar Satellite Power systems.** M. Trella and K. K. Reinhartz (ESA, Noordwijk, Netherlands). In: *Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978*. London, Royal Aeronautical Society, 1979. 17 p. 18 refs.

It is pointed out that energy-related problems are potentially much more serious in Europe than in the U.S. The proposal is, therefore, made that European countries should investigate the prospects offered by the SPS as a future source of a part of the energy needed by them. An outline is presented of the specifically European problems which have to be investigated to evaluate the SPS concept. Possible European activities are examined, taking into account a concept evaluation, studies related to energy conversion, space construction and operation, power transmission and distribu-

## 10 SOLAR POWER SATELLITE SYSTEM

tion, transportation, and the selection criteria for technological research. Program considerations and financial aspects are also explored. G.R.

**A79-31925 \*** *The Solar Power Satellite concept - Towards the future.* C. C. Kraft, Jr. (NASA, Johnson Space Center, Houston, Tex.). In: *Energy and Aerospace; Proceedings of the Anglo-American Conference, London, England, December 5-7, 1978.* London, Royal Aeronautical Society, 1979. 12 p.

An evolutionary program phasing with respect to the development of a Solar Power Satellite (SPS) is considered, taking into account concept identification, concept evaluation, exploratory research, space technology projects, system development, and commercial operations. At the present time the concept evaluation phase of the program is underway. This phase is scheduled for completion in 1980. It will result in a recommendation as to whether the concept should be explored further and if so, in what manner. The recommendation will be based on technical feasibility, economic and environmental considerations, and comparisons with other potential systems of the future. It is premature to speculate on the conclusions and recommendations from the evaluation program as to whether the program should proceed to the next phase. G.R.

**A79-32721** *First steps to the Solar Power Satellite.* P. E. Glaser (Arthur D. Little, Inc., Cambridge, Mass.), G. M. Hanley (Rockwell International Corp., Downey, Calif.), R. H. Nansen (Boeing Aerospace Co., Seattle, Wash.), and R. L. Kline (Grumman Aerospace Corp., Bethpage, N.Y.). *IEEE Spectrum*, vol. 16, May 1979, p. 52-58.

The Solar Power Satellite (SPS) concept is described in the light of the so-called reference system, developed by the Department of Energy and NASA as a guideline for evaluating the SPS's technical, environmental, economic, and societal problems. The silicon solar array design is considered, and it is noted that in order to extend the life of the cells the reference design features CO<sub>2</sub> lasers mounted on the satellite to anneal the cells. The selected methods for transmitting power to earth, the questions of where and how to build the satellites and ground stations, and the projected design of the transportation system are also considered. The problems facing the SPS system are reviewed. A.A.

**A79-34737 \*** *An economic analysis of a commercial approach to the design and fabrication of a space power system.* Z. Putney (Solarex Corp., Rockville, Md.) and J. Been (NASA, Lewis Research Center, Cleveland, Ohio). In: *Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.* New York, American Institute of Aeronautics and Astronautics, Inc., 1979. p. 300-305. 6 refs. (AIAA 79-0914)

This paper discusses a commercial approach to the design and fabrication of an economical space power system. With the advent of the space shuttle, steps can be taken to back away from the presently used space qualified approach in order to reduce cost of space hardware by incorporating, where possible, commercial design, fabrication, and quality assurance methods. Cost reductions are projected through the conceptual design of a 2 kW space power system built with the capability for having serviceability. The approach to system costing that has been used takes into account both the constraints of operation in space and commercial production engineering approaches. The cost of this power system reflects a variety of cost/benefit tradeoffs that would reduce system cost as a function of system reliability requirements, complexity, and the impact of rigid specifications. A breakdown of the system design, documentation, fabrication and reliability and quality assurance cost estimates are detailed. (Author)

**A79-34846 \*** *New methods for the conversion of solar energy to R. F. and laser power.* J. W. Freeman, W. B. Colson, and S. Simons (Rice University, Houston, Tex.). *Princeton University and American Institute of Aeronautics and Astronautics, Conference on Space Manufacturing Facilities, 4th, Princeton University, Princeton, N.J., May 14-17, 1979, AIAA Paper 791416.* 7 p. 8 refs.

This paper discusses two new devices which may have application to space deployed solar energy conversion and transmission systems, the photoklystron and the free electron laser. The photoklystron converts solar energy directly to RF radiation. It operates on the principle of the klystron with the cathode replaced by a photoemitting surface. We have tested a model which oscillates at 30 MHz. This laboratory model requires two low-voltage bias voltages which can be supplied by dc solar cells. Concepts for a self biasing device are also being considered. The photoklystron is expected to be easier and less expensive to manufacture than solid state solar cells. A photoklystron array could replace the high voltage solar cell array, slapping and klystron transmitter in the SPS. The second device, the free electron laser (FEL), converts energy from a relativistic electron beam to narrow band electromagnetic energy, tuneable from the infrared to the ultraviolet. Because the lasing electrons are not bound in atomic energy levels the ultimate efficiency of the FEL is expected to exceed that of conventional lasers, possibly making lasers a practical means of energy conversion and transmission in space systems. (Author)

**A79-35488** *The development of solar power satellites (La mise au point de satellites à énergie solaire).* P. E. Glaser (Arthur D. Little, Inc., Cambridge, Mass.). *Revue de l'Energie*, vol. 30, Mar. 1979, p. 246-266. In French. (Translation).

A 5 GW solar power satellite employing silicon or gallium arsenide photovoltaic cells is being considered for development. Power transmission schemes and the transport system needed to orbit the materials and personnel for the solar power satellite are discussed. Cost projections, technological problems associated with receiving antennas, and possible environmental effects of the solar power satellite also receive attention. J.M.B.

**A79-37842** *International Conference on Future Energy Concepts, London, England, January 30-February 1, 1979. Proceedings.* Conference sponsored by the Institution of Electrical Engineers, London, Institution of Electrical Engineers (IEE Conference Publication, No. 171), 1979. 460 p. \$46.

Papers are presented on solar energy utilization, wave power experiments, geothermal energy, tidal power, MHD power generation, wind energy systems, and hydrogen energy. Particular consideration is given to windpower generation on a large scale, the prospects of a biological-photochemical approach to the utilization of solar energy, tidal and river current energy systems, and satellite solar power stations. B.J.

**A79-37844** *Satellite solar power stations - Current status and prospects.* P. O. Collins (Imperial College of Science and Technology, London, England). In: *International Conference on Future Energy Concepts, London, England, January 30-February 1, 1979, Proceedings.* London, Institution of Electrical Engineers, 1979, p. 21-25. 28 refs.

A brief review of the satellite solar power station concept is presented with attention given to technical environmental aspects. Cost estimates are discussed and consideration is given to the possible use of extraterrestrial materials and to UK interest in the project. B.J.

**A79-38201 \*** *Space Laser Power System.* W. S. Jones (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). *American Institute of Aeronautics and Astronautics, Terrestrial Energy Systems Conference, Orlando, Fla., June 4-6, 1979, Paper 79-1013.* 7 p. 12 refs.

The Space Laser Power System (SLPS) concept developed for NASA requires only a few acres of protected area around the ground receiver in contrast to tens of thousands of acres for the microwave beam of the Solar Power Satellite (SPS) concept, although the SLPS must include features to insure safe operations. For instance, in order to overcome the inability to penetrate heavy clouds (the major inconvenience), multiple ground stations and switching to clear sites is suggested. A description of different parts of the SLPS is presented, with consideration given to the electrical discharge laser (EDL) and the solar pumped laser (SPL) space options, also noting some systems concepts. It is shown that the overall efficiency from solar energy in space to electrical output on the ground for the microwave SPS is 7.3%, for the EDL system is 6.4%, and for the SPL system is 9.4%. V T

**A79-38292 \*** **Solar pumped lasers for space power transmission.** R. Taussig, C. Bruzzone, L. Nelson, D. Quimby (Mathematical Sciences Northwest, Inc., Bellevue, Wash.), and W. Christiansen (Washington University, Seattle, Wash.). *American Institute of Aeronautics and Astronautics, Terrestrial Energy Systems Conference, Orlando, Fla., June 4-6, 1979, Paper 79-1015* 18 p. 40 refs. Contract No. NAS3-21134

Multi-Megawatt CW solar pumped lasers appear to be technologically feasible for space power transmission in the 1990s time frame. A new concept for a solar pumped laser is presented which utilizes an intermediate black body cavity to provide a uniform optical pumping environment for the laser, either CO or CO<sub>2</sub>. Reabsorption losses are minimized with resulting high efficiency operation. A 1 MW output laser may weigh as little as 8000 kg including solar collector, black body cavity, laser cavity and ducts, pumps, power systems and waste heat radiator. The efficiency of such a system will be on the order of 10 to 20%. Details of the new concept, laser design, comparison to competing solar powered lasers and applications to a laser solar power satellite (SPS) concept are presented. (Author)

**A79-38374** **Solar power satellites. Microwaves deliver the power.** W. C. Brown (Raytheon Co., Microwave and Power Tube Div., Waltham, Mass.). *IEEE Spectrum*, vol. 16, June 1979, p. 36-42

While microwave power transmission from the Solar Power Satellite (SPS) network provides such advantages as availability of the sun's energy for more than 99% of the year, supply of five GW of power from each SPS and dc-to-dc transmission efficiency of more than 60%, there are three possible environmental problems associated with the SPS system: radio frequency interference (RFI), local heating of the ionosphere, and possibly harmful biological effects. The RFI and ionospheric problems are being studied by DOE and safety features, such as a pilot beam for the transmitting antenna to track and be planned, to keep microwave beams from wandering off target and affecting people. The microwave transmission system envisioned in the DOE-NASA reference design comprises three parts:

1) The conversion of dc power to microwave power; 2) The formation and control of microwave beams; and 3) The collection of the microwave energy and its conversion into dc energy. The design uses the linear beam tube in its klystron format, however, the crossed field device in either magnetron-directional amplifier or amplatron is still an option for the final design. V T

**A79-40490 \*** **New energy conversion techniques in space, applicable to propulsion.** A. Hertzberg (Washington University, Seattle, Wash.) and K. C. Sun (Lockheed Research Laboratories, Palo Alto, Calif.). *AIAA, SAE, and ASME, Joint Propulsion Conference, 15th, Las Vegas, Nev., June 18-20, 1979, AIAA Paper 79-1338* 43 p. 25 refs. Grant No. NGL-48-002-044

The powering of aircraft with laser energy from a solar power satellite may be a promising new approach to the critical problem of the rising cost of fuel for aircraft transportation systems. The result

is a nearly fuelless, pollution-free flight transportation system which is cost-competitive with the fuel-conservative airplane of the future. The major components of this flight system include a laser power satellite, relay satellites, laser-powered turbofans and a conventional airframe. The relay satellites are orbiting optical systems which intercept the beam from a power satellite and refocus and redirect the beam to its next target. (Author)

**A79-44160** **Energy analysis of the Solar Power Satellite.** R. A. Herendeen, T. Kary, and J. Rebitzer (Illinois University, Urbana, Ill.). *Science*, vol. 205, Aug. 3, 1979, p. 451-454, 25 refs.

The energy requirements to build and operate the proposed Solar Power Satellite are evaluated and compared with the energy it produces. Because the technology is so speculative, uncertainty is explicitly accounted for. For a proposed 10-gigawatt satellite system, the energy ratio, defined as the electrical energy produced divided by the primary nonrenewable energy required over the lifetime of the system, is of order 2, where a ratio of 1 indicates the energy breakeven point. This is significantly below the energy ratio of today's electricity technologies such as light-water nuclear or coal-fired electric plants. (Author)

**A79-44249** **Solar power satellite ground stations.** R. Andryczyk, P. Foldes, J. Chetok (General Electric Co., Space Div., Valley Forge, Pa.), and B. M. Kaupang (General Electric Co., Schenectady, N.Y.). *IEEE Spectrum*, vol. 16, July 1979, p. 51-55

The main ground installation for a solar power satellite system, employing a low-gain 10 km diameter rectifying antenna (rectenna), a medium-voltage dc power collecting grid, dc/ac converters, and a high-voltage ac power collecting grid, is examined. It is found that the rectenna can collect 5 GW of power at 2.45 GHz at a theoretical maximum power density of 24.3 mW/cm<sup>2</sup> squared, if minimal atmospheric attenuation is assumed. The size and configuration of the rectenna are studied and characteristics, including field distribution (Gaussian), total transmit power (7.1249 GW), edge taper (-8.8 dB) and nominal dimensions (NS 11.48 km and NE 9.4 km), are noted. The dipole assembly of the rectenna, containing a circuit that matches the impedance of the dipole to the impedance of the diode circuit is analyzed and specific detail is given to the study of the rectenna's power collecting system that uses several thousand panels to make up a 500-kW module. It is concluded that the most important characteristics of the rectenna are the availability of its power output and longevity; the expected overhaul is only once every thirty years. C.F.W.

**A79-44277 \*** **The solar power satellite concept.** P. E. Glaser (Arthur D. Little, Inc., Cambridge, Mass.). *AIAA Student Journal*, vol. 17, Summer 1979, p. 32-41, 25 refs.

A method to utilize solar energy through solar power satellites (SPS) is presented. The electricity produced by solar energy conversion will be fed to microwave generators forming part of a planar, phased array transmitting antenna, which in turn is designed to direct a microwave beam to one or more receiving antennas. Variations in solar power output due to eclipses, equinox periods and other predictable interruptions, are expected to range from 1.309 kW/kg m to 1.399 kW/kg m. Technological options for solar energy conversion, including photovoltaic and thermal-electric processes are described. Attention is also given to the assembly and maintenance of SPS, economic and environmental implications, as well as microwave biological effects and other impacts, which include thermal pollution, land deposition and resource consumption. C.F.W.

**A79-46699 \*** **Effects of plasma sheath on solar power satellite array.** L. W. Parker (Lee W. Parker, Inc., Concord, Mass.). *American Institute of Aeronautics and Astronautics, Fluid and Plasma Dynamics Conference, 12th, Williamsburg, Va., July 23-25, 1979, Paper 79-1507* 8 p. 11 refs. NASA supported research.



## 10 SOLAR POWER SATELLITE SYSTEM

The structure of the plasma sheath and equilibrium voltage distribution of a high-power solar array governs various kinds of plasma-interaction phenomena and array losses. Sheath effects of a linearly-connected array are investigated for GEO. Although the array may be large, the thin-sheath-limit analysis may be invalid, necessitating numerical methods. Three-dimensional computer calculations show that potential barriers and overlapping sheaths can occur, i.e., structures not predictable under the thin-sheath-limit analysis, but nevertheless controlling the distribution of plasma currents impacting on the array. (Author)

**A79-48026** Energy for the year 2000 - The SPS concept (Energie für das Jahr 2000 - Das SPS-Konzept). G. Tschulen, *Nachrichten Elektronik*, vol. 33, Aug. 1979, p. 249-254, 7 refs. In German.

The solar power satellite (SPS) system is examined. Different aspects of the project are discussed including the energy conversion technology such as solar cells of different compounds and thermoelectric converters. Also covered are the microwave transmission system, and environmental concerns such as biological effects and the dispersion of microwaves. Consideration is also given to realization of the project through the Space Shuttle. Finally, the development program of the SPS project is discussed. M.E.P.

**A79-50399** Solar power satellite - Putting it together. R. W. Johnson (Grumman Aerospace Corp., Bethpage, N.Y.) *IEEE Spectrum*, vol. 16, Sept. 1979, p. 37-40.

The problems of constructing a solar power satellite in earth orbit are surveyed. Consideration is given to such points as the need for an assembly line in space, for lightweight yet strong and durable materials, for a completely new heavy lift launch vehicle and for special manipulative tools for assembly work. Advanced composite materials are discussed as well as the question of whether to build in low or high earth orbit. Construction techniques described include an automatic beam making machine and remote work stations. Finally, it is concluded that the development of construction techniques for the SPS will have other uses which will reduce the R&D costs chargeable to the solar power satellite. M.E.P.

**A79-51891** Results from Symposium on Future Orbital Power Systems Technology Requirements. S. Gortland (NASA, Lewis Research Center, Cleveland, Ohio). In: Intersociety Energy Conversion Engineering Conference, 14th, Boston, Mass., August 5-10, 1979, Proceedings, Volume 2. Washington, D.C., American Chemical Society, 1979, p. 1203-1206.

Technology deficiencies, adequacy of current programs, and recommendations for reducing the testing and risks involved in future orbital energy systems made at the NASA Symposium are summarized. Photovoltaic space power system problems, including structural dynamics and attitude control problems due to solar array flexing, solar cell radiation resistance, manufacturing capability, and cost reduction, solar arrays including inflatable arrays, spectrum selection to increase efficiency, and polymer coatings for cells; battery technology, the endurance data base for fuel cell and electrolysis technology, and power management were discussed. Other topics considered were laser microwave power transmission, thermal management, nuclear power systems, and environmental interactions. It was concluded that a 'front end' system study is needed in each area and current programs for multi-hundred kW power systems are under way. A.T.

**A79-51941** Computer modeling for a space power transmission system. S. M. Rathjen (Boeing Aerospace Co., Seattle, Wash.) and D. K. Reynolds (Washington University, Seattle, Wash.). In: Intersociety Energy Conversion Engineering Conference, 14th, Boston, Mass., August 5-10, 1979, Proceedings, Volume 2. Washington, D.C., American Chemical Society, 1979,

p. 1480-1485, 12 refs. Contracts No. NAS9-15636; No. NAS9-15196.

The paper summarizes the development of a computer program that simulates the performance of a large phased array antenna composed of 7220 smaller subarrays, each made up of klystron modules which act as individual radiators. The purpose of this program is to (1) study the far field pattern near the rectenna, (2) calculate the beam efficiency, and (3) observe the grating lobe behavior. Attention is given to the computer program which consists of a main program and four subroutines, as well as to the system configurations. The effects of amplitude, phase and random subarray failures are examined and an error budget was specified for 10 to the 0 phase error, + or - 1 dB amplitude error, and a 2% random failure rate. C.F.W.

**A79-51943** The technology base for the microwave power transmission system in the SPS. W. C. Brown (Raytheon Co., Waltham, Mass.). In: Intersociety Energy Conversion Engineering Conference, 14th, Boston, Mass., August 5-10, 1979, Proceedings, Volume 2. Washington, D.C., American Chemical Society, 1979, p. 1492-1499, 13 refs.

The microwave power transmission system in the Solar Power Satellite (SPS) is reviewed in terms of the existing technology base. This technology base consists of: (1) the experience that has been obtained from complete transmission systems including the inter-conversion of dc and microwave energy at both ends of the system and all of the interfaces between various parts of the system; (2) the efficient conversion of dc power into microwave power; (3) the microwave beam link itself, and (4) the efficient collection of microwave power at the receiving end of the link and its conversion back into dc power. Special emphasis is placed upon recent additions to this technology base and also upon the critical nature of some of the microwave technology that is needed to meet the SPS requirements. (Author)

**A79-53301** Superlight rotating reflectors in space. A. V. Luk'yanov (Moskovskiy Gosudarstvennyy Universitet, Moscow, USSR). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-112*, 14 p. 10 refs.

The use of large mirror reflectors in space to control solar and electromagnetic radiation with specific mass of order of 1 gm/sq m or less is examined. Such reflectors may be used in space energetics for concentration of solar energy for its conversion into a microwave beam and transmission to earth, for illuminating the earth surface with reflected sunlight, weather control, and research. Design and construction of the reflector, its main parameters including angular and rotative speed, and the control of rotation, precession, and nutation, and the position control in space are discussed. The control of its orientation and space position is performed with solar energy and light pressure, and the film strength permits concentrators with a radii of several kilometers and nearly flat reflectors for lighting application with a radii of several hundred meters. More than a hundred reflectors of 600 m diameter can be assembled at a station at the 1000 km height yearly, but a difficult problem of superthin film mass production and assembly technology problems must be solved to realize this program. A.T.

**A79-53382** Cost comparisons for the use of nonterrestrial materials in space manufacturing of large structures. E. H. Bock and R. C. Riley (General Dynamics Corp., Convair Div., San Diego, Calif.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-115*, 24 p. 16 refs. NASA sponsored research.

This paper presents results of a study sponsored by NASA to evaluate the relative merits of constructing solar power satellites (SPS) using resources obtained from the earth and from the moon. Three representative lunar resources utilization (LRU) concepts are developed and compared with a previously defined earth baseline

concept. Economic assessment of the alternatives includes cost determination, economic threshold sensitivity to manufacturing cost variations, cost uncertainties, program funding schedule, and present value of costs. Results indicate that LRU for space construction is competitive with the earth baseline approach for a program requiring 100,000 metric tons per year of completed satellites. LRU can reduce earth-launched cargo requirements to less than 10% of that needed to build satellites exclusively from earth materials. LRU is potentially more cost effective than earth-derived material utilization, due to significant reductions in both transportation and manufacturing costs. Because of uncertainties, cost-effectiveness cannot be ascertained with great confidence. The probability of LRU attaining a lower total program cost within the 30-year program appears to range from 57 to 93%.

(M.E.P.)

**A79-53334** **Solar power satellites for Europe.** J. Ruth and W. Westphal (Berlin, Technische Universität, Berlin, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-177*. 12 p. 6 refs.

The potential utilization of Solar Power Satellites (SPS) as baseload powerplants for Western European countries is studied. Attention is given to significant differences with the USA in factors such as geographical, political, organizational, orbital, and industrial. Among the problems discussed which must be solved prior to full scale SPS development is the impact on the environment. Finally recommendations are made and conclude that the analysis of specific European problems has to be extended and refined, a joint group of US and European planners and engineers must work out the specifications for a cooperation in a technology program after 1982, and a specific European experimental program on the impacts of SPS installation and operation on the environment has to be implemented.

(M.E.P.)

**A79-53335** **European technology applicable to Solar Power Satellite Systems (SPS).** H. Stoewer (ESA, System Engineering Dept., Noordwijk, Netherlands), B. Tilgner (ESA, Technology, Industry and Infrastructure Dept., Paris, France), and D. Kasing (ESA, Spacecraft Power Supplies Div., Noordwijk, Netherlands). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-174*. 23 p. 14 refs.

The paper reviews European space technology activities that have potential for application in an SPS program. Existing and developing European space technologies are compared with the expected requirements of a study assessment and early key technology verification investigation for the SPS concept. It is shown that a number of existing European space technologies and the results of current development efforts apply well to this. Topics discussed include solar energy conversion, electrical energy conversion, electrical to microwave conversion, microwave power transmission, space structures, attitude and orbit control, thermal control, and ground receiver stations.

(M.E.P.)

**A79-53336** **Satellite solar power station designs with concentrators and radiating control.** A. V. Luk'ianov (Moskovskii Gosudarstvennyi Universitet, Moscow, USSR). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-176*. 6 p. 6 refs.

The paper investigates the application of superlight rotating parabolic concentrators for space energetics. The total mass of all high temperature converters considered, does not exceed that of the transmitting antenna. Attention is given to a design with two concentrators weighing 30 Mg, which offers the possibility of control of mast orientation by using thin movable mirrors of tungsten or other thermoresistant material in the concentrator foci. In this manner reflection of an insignificant part of concentrated energy in the corresponding direction will create the necessary thrust. Also

discussed are: a satellite power station (SSPS) with numerous concentrators and SSPS with solar cells. Here eight adjustable mirrors situated along the periphery could work as concentrators as well as correction engines.

(M.E.P.)

**A79-53337** **A space power station without movable parts.** M. Poppril (Czechoslovakia Akademie Ved, Astronomický Ústav, Ondřejov, Czechoslovakia). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-177*. 10 p.

An area of suitable shape could be used as a receiver of solar radiation ('outer' surface) and a microwave antenna ('inner' surface). Elimination of the necessity to revolve the panels with cells, delivery of power according to the average demand and other features of this SPS concept are discussed.

(Author)

**A79-53338** **Use of a large space structure as an orbital depot for hazardous wastes.** P. Natenbrink (ERI O Raumfahrttechnik GmbH, Bremen, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-209*. 41 p.

Some concepts are presented for the use of a large orbital space depot for hazardous wastes. Among the advantages cited for such a concept are: safe storage of waste over a very long time, insensitivity to geological changes on earth, no pollution risk of life environment, and low sensitivity to sabotage. Factors affecting the implementation of such a project include: public acceptance, technical definition, program implementation, legal issues, and organizational structure. Among the conclusions it is noted that high absolute costs of concept realization should not be a deterrent, since they must be compared to total losses/costs associated with keeping wastes on earth.

(M.E.P.)

**A79-53487** **A power transmission concept for a European SPS system.** R. A. Henderson (British Aerospace, Dynamics Group, Bristol, England). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-14*. 15 refs.

A hybrid SPS system is proposed in which solar power is collected in geosynchronous orbit and transmitted by a concentrated laser beam to a receiver mounted on a 2.6 km diam rigid balloon stationed at approximately 30 km altitude. Power is converted to microwave energy and beamed to the ground to multiple rectennas which are significantly reduced from those of the direct microwave transmission to ground concept. Waste heat from the energy conversion process would provide power to maintain a stable balloon platform which could perform other functions related to earth observation and communications.

(Author)

**N79-21630\*** **National Aeronautics and Space Administration, Washington, D. C.**

**SATELLITE POWER SYSTEM: CONCEPT DEVELOPMENT AND EVALUATION PROGRAM. REFERENCE SYSTEM REPORT**

Jan 1979 321 p refs Prepared in cooperation with DOE, Washington, D. C.

(NASA TM-79762, DOE/ER-0023) Avail NTIS HC A14/MF A01 CSCL 10B

The Satellite Power System (SPS) Reference System is discussed and the technical and operational information required in support of environmental, socioeconomic, and comparative assessment studies are emphasized. The reference System concept features a gallium-aluminum-arsenide, and silicon solar cell options. Other aspects of an SPS are the construction of bases in space, launch and mission control bases on earth, and fleets of various transportation vehicles to support the construction and maintenance operations of the satellites.

(M.M.M.)

## 10 SOLAR POWER SATELLITE SYSTEM

**N79-22193\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

### **AN ECONOMIC ANALYSIS OF A COMMERCIAL APPROACH TO THE DESIGN AND FABRICATION OF A SPACE POWER SYSTEM**

Zeml Putney (Solarex Corp., Rockville, Md.) and Julian Been  
1979 8 p refs Presented at the Conf on Adv Technol for  
Future Space Systems, Hampton, S-11 May 1979, sponsored  
by AIAA

(NASA-TM-79153, E-1009) Avail NTIS HC A02/MF A01  
CSCL 10A

A commercial approach to the design and fabrication of an  
economical space power system is presented. Cost reductions  
are projected through the conceptual design of a 2 kW space  
power system built with the capability for having serviceability.  
The approach to system costing that is used takes into account  
both the constraints of operation in space and commercial  
production engineering approaches. The cost of this power system  
reflects a variety of cost/benefit tradeoffs that would reduce  
system cost as a function of system reliability requirements,  
complexity, and the impact of rigid specifications. A breakdown  
of the system design, documentation, fabrication, and reliability  
and quality assurance cost estimates are detailed. J M S

### **N79-22261\*** Vermont Univ., Burlington. Dept. of Chemistry **NEW HIGHLY CONDUCTING COORDINATION COMPOUNDS**

D. B. Brown, K. Carreno, P. Day, B. Hoffman, H. J. Keller, W.  
A. Little, A. E. Underhill, and J. M. Williams 17 Jan 1979  
11 p Submitted for publication

(Contract N00014-75-C-0756)

(AD-A064735, TR-11) Avail NTIS HC A02/MF A01 CSCL  
07/3

Structural features of coordination compounds which lead  
to high electrical conductivity are examined. Certain features  
are shown to be necessary for high conductivity, and suggestions  
are made concerning future synthetic efforts required in the search  
for molecular metals. Author (GRA)

### **N79-22616\*** Boeing Aerospace Co., Seattle, Wash. **SYSTEMS DEFINITION SPACE BASED POWER CONVERSION SYSTEMS: EXECUTIVE SUMMARY Final Report**

1977 29 p refs

(Contract NAS8-31628)

(NASA-CR-150209, D180-20309-1) Avail NTIS  
HC A03/MF A01 CSCL 10B

Potential space-located systems for the generation of  
electrical power for use on earth were investigated. These systems  
were of three basic types: (1) systems producing electrical power  
from solar energy; (2) systems producing electrical power from  
nuclear reactors; (3) systems for augmenting ground-based solar  
power plants by orbital sunlight reflectors. Configurations  
implementing these concepts were developed through an  
optimization process intended to yield the lowest cost for each.  
A complete program was developed for each concept, identifying  
required production rates, quantities of launches, required facilities,  
etc. Each program was costed in order to provide the electric  
power cost appropriate to each concept. G Y

### **N79-22617\*** ECON, Inc., Princeton, N. J. **SPACE BASED SOLAR POWER CONVERSION AND DELIVERY SYSTEMS STUDY. VOLUME 1: EXECUTIVE SUMMARY Final Report, 30 Sep. 1976 - 31 Mar. 1977**

31 Mar 1977 49 p 5 Vol

(Contract NAS8-31308)

(NASA-CR-150294, Rept 77-145-1-Vol. 1) Avail NTIS  
HC A03/MF A01 CSCL 10B

The research concerning space-based solar power conversion  
and delivery systems is summarized. The potential concepts for  
a photovoltaic satellite solar power system was studied with  
emphasis on ground output power levels of 5,000 MW and

10,000 MW. A power relay satellite, and certain aspects of the  
economics of these systems were also studied. A second study  
phase examined in greater depth the technical and economic  
aspects of satellite solar power systems. Throughout this study,  
the focus was on the economics of satellite solar power. The  
results indicate technical feasibility of the concept, and provide  
a preliminary economic justification for the first phase of a  
substantial development program. A development program  
containing test satellites is recommended. Also, development of  
alternative solar cell materials (other than silicon) is recom-  
mended. F O S

### **N79-22618\*** Grumman Aerospace Corp., Bethpage, N.Y. **SPACE BASED SOLAR POWER CONVERSION AND DELIVERY SYSTEMS STUDY. VOLUME 2: ENGINEERING ANALYSIS Final Report**

31 Mar 1977 264 p refs Prepared for ECON, Inc., Princeton,  
N. J.

(Contract NAS8-31308)

(NASA-CR-150295) Avail NTIS HC A12/MF A01 CSCL  
10B

The technical and economic feasibility of Satellite Solar  
Power Systems was studied with emphasis on the analysis and  
definition of an integrated strawman configuration concept, from  
which credible cost data could be estimated. Specifically, system  
concepts for each of the major subsystems were formulated,  
analyzed, and iterated to the degree necessary for establishing  
an overall, workable baseline system design. Cost data were  
estimated for the baseline and used to conduct economic analyses.  
The baseline concept selected was a 5-GW crystal silicon  
truss-type photovoltaic configuration, which represented the most  
mature concept available. The overall results and major findings,  
and the results of technical analyses performed during the final  
phase of the study efforts are reported. F O S

### **N79-22619\*** Raytheon Co., Wayland, Mass. Equipment Div. **SPACE BASED SOLAR POWER CONVERSION AND DELIVERY SYSTEMS STUDY. VOLUME 3: MICROWAVE POWER TRANSMISSION STUDIES Final Report**

1 Mar 1977 195 p refs Prepared for ECON, Inc., Princeton,  
N. J.

(Contract NAS8-31308)

(NASA-CR-150296) Avail NTIS HC A09/MF A01 CSCL  
10B

The Microwave Power Beam Ionosphere effects and critical  
interfaces between the Microwave Power Transmission System  
(MPTS) and the Satellite were studied as part of the NASA/MSFC  
continuing research on the feasibility of power transmission from  
geosynchronous orbit. Theoretical predictions of ionospheric  
modifications produced by the direct interaction of the MPTS  
on the earth's upper atmosphere are used to determine their  
impact on the performance of the Microwave Power Beam and  
Pilot Beam System as well as on other RF systems affected by  
the ionosphere. A technology program to quantitatively define  
these interactions is developed. Critical interface areas between  
the MPTS and the satellite which could have a major impact  
on cost and performance of the power system are identified  
and analyzed. The areas selected include use of either a 20 kV  
versus 40 kV Amplitron, thermal blockage effects of Amplitron  
heat radiation by the satellite structure, effect of dielectric  
carry-through structure on power beam, and effect of material  
sublimation on performance of the Amplitron in Geosynchronous  
Orbit. F O S

### **N79-22620\*** Little (Arthur D.), Inc., Cambridge, Mass. **SPACE BASED SOLAR POWER CONVERSION AND DELIVERY SYSTEMS STUDY. VOLUME 4: ENERGY CONVERSION SYSTEMS STUDIES Final Report**

29 Mar 1977 74 p refs Prepared for ECON, Inc., Princeton,  
N. J.

(Contract NAS8-31308)

(NASA-CR-150297, C-78127-Vol. 4) Avail NTIS  
HC A04/MF A01 CSCL 10B

Solar cells and optical configurations for the SSPS were examined. In this task, three specific solar cell materials were examined: single crystal silicon, single crystal gallium arsenide, and polycrystalline cadmium sulfide. The comparison of the three different cells on the basis of a subsystem parametric cost per kW of SSPS-generated power at the terrestrial utility interface showed that gallium arsenide was the most promising solar cell material at high concentration ratios. The most promising solar cell material with no concentration was dependent upon the particular combination of parameters representing cost, mass and performance that were chosen to represent each cell in this deterministic comparative analysis. The potential for mass production, based on the projections of the present state-of-the-art would tend to favor cadmium sulfide in lieu of single crystal silicon or gallium arsenide solar cells. F O S

**N79-22632\*** Rockwell International Corp., Downey, Calif. Space Systems Group.  
**SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C, VOLUME 3: EXPERIMENTAL VERIFICATION DEFINITION** Final Report  
Mar 1979 152 p  
(Contract NAS8-32475)  
(NASA CR 161214, SSD-79-0010-3) Avail NTIS  
HC A08/MF A01 CSCL 108

An environmentally oriented microwave technology exploratory research program aimed at reducing the uncertainty associated with microwave power system critical technical issues is described. Topics discussed include: (1) Solar Power Satellite System (SPS) development plan elements, (2) critical technology issues related to the SPS preliminary reference configuration, (3) pilot plant to demonstrate commercial viability of the SPS system, and (4) research areas required to demonstrate feasibility of the SPS system. Progress in the development of advanced GaAs solar cells is reported along with a power distribution subsystem. J M S

**N79-22633\*** Rockwell International Corp., Downey, Calif. Space Systems Group.  
**SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C, VOLUME 5: SPECIAL EMPHASIS STUDIES** Final Report  
G. Hanley Mar 1979 265 p refs  
(Contract NAS8-32475)  
(NASA CR 161215, SSD-79-0010-5) Avail NTIS  
HC A12/MF A01 CSCL 108

Specific areas were analyzed and identified as high priority for more in-depth analysis. These areas were: (1) rectenna constructability, (2) satellite constructability, (3) support systems constructability, (4) space environmental analysis, and (5) special end-to-end analyses. Baseline requirements specified coplanar solar blankets and an end-mounted antenna, utilizing either GaAlAs solar cells and employing a CR of 2 or Si cells. Several configurations were analyzed. Utilizing the preferred configuration as a baseline, a satellite construction base was defined, precursor operations incident to establishment of orbital support facilities identified, and the satellite construction sequence and procedures developed. Since the baseline specifies only instead of one hundred and twenty satellites to be constructed in a thirty year period, mass flow to orbit requirements were revised and new traffic models established. Launch site requirements (exclusive of actual launch operations) in terms of manpower and building space were defined. J M S

**N79-22634\*** Rockwell International Corp., Downey, Calif. Space Systems Group.  
**SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C, VOLUME 6: IN-DEPTH ELEMENT INVESTIGATION** Final Report  
G. Hanley Mar 1979 97 p refs  
(Contract NAS8-32475)  
(NASA CR 161216, SSD-79-0010-6) Avail NTIS  
HC A05/MF A01 CSCL 108

Computer assisted design of a gallium arsenide solid state dc-to-RF converter with supportive fabrication data was investigated. Specific tasks performed include: computer program checkout, amplifier comparisons, computer design analysis of GaAs solar cells, and GaAs diode evaluation. Results obtained in the design and evaluation of transistors for the microwave space power system are presented. J M S

**N79-23483\*** Boeing Aerospace Co., Seattle, Wash.  
**SYSTEMS DEFINITION SPACE BASED POWER CONVERSION SYSTEMS** Final Report, 8 Jun. 1975 - 30 Nov. 1976  
30 Nov 1976 95 p refs. Prepared in cooperation with Garrett Corp., Los Angeles, and Thermo Electron Corp.  
(Contract NAS8-31628)  
(NASA CR 150268, D180-20309-2) Avail NTIS  
HC A05/MF A01 CSCL 108

Potential space located systems for the generation of electrical power for use on Earth are discussed and include: (1) systems producing electrical power from solar energy, (2) systems producing electrical power from nuclear reactors, and (3) systems for augmenting ground-based solar power plants by orbital sunlight reflectors. Systems (1) and (2) would utilize a microwave beam system to transmit their output to Earth. Configurations implementing these concepts were developed through an optimization process intended to yield the lowest cost for each. A complete program was developed for each concept, identifying required production rates, quantities of launches, required facilities, etc. Each program was costed in order to provide the electric power cost appropriate to each concept. A R H

**N79-23484\*** Rockwell International Corp., Downey, Calif. Satellite Systems Div.  
**SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C, VOLUME 1: EXECUTIVE SUMMARY** Final Report  
G. M. Hanley Mar 1979 66 p refs 7 Vol.  
(Contract NAS8-32475)  
(NASA CR 161218, SSD-79-0010-1 Vol 1) Avail NTIS  
HC A04/MF A01 CSCL 108

The Department of Energy (DOE) is currently conducting an evaluation of approaches to provide energy to meet demands in the post-2000 time period. The Satellite Power System (SPS) is a candidate for producing significant quantities of base load power using solar energy as the source. The SPS concept is illustrated for a solar photovoltaic concept. A satellite, located at geosynchronous orbit, converts solar energy to dc electrical energy using large solar arrays. This study is a continuing effort to provide system definition data to aid in the evaluation of the SPS concept. G Y

**N79-23485\*** Rockwell International Corp., Downey, Calif. Satellite Systems Div.  
**SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C, VOLUME 2, PART 1: SYSTEM ENGINEERING** Final Report  
G. M. Hanley Mar 1979 267 p refs 7 Vol.  
(Contract NAS8-32475)  
(NASA CR 161219, SSD-79-0010-2 1 Vol 2 Pt 1) Avail NTIS  
HC A12/MF A01 CSCL 108

Volume 2, Part 1, of a seven volume report is presented. Part 1 encompasses Satellite Power Systems (SPS) systems engineering aspects and is divided into three sections. The first section presents descriptions of the various candidate concepts considered and conclusions and recommendations for a preferred concept. The second section presents a summary of results of the various trade studies and analysis conducted during the course of the study. The third section describes the Photovoltaic Satellite Based Satellite Power System (SPS) Point Design as it was defined through studies performed during the period January 1977 through March 1979. G Y



## 10 SOLAR POWER SATELLITE SYSTEM

**N79-23486\*** Rockwell International Corp., Downey, Calif. Satellite Systems Div.

### **SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 2, PART 2: SYSTEM ENGINEERING, COST AND PROGRAMMATICS Final Report**

G. M. Hanley Mar 1979 113 p refs 7 Vol.

(Contract NAS8-32475)

(NASA-CR-161220, SSD-79-0010-2-2-Vol-2-Pt-2) Avail NTIS HC A06/MF A01 CSCL 10B

Volume 2, Part 2, of a seven volume Satellite Power Systems (SPS) report is presented. Part 2 covers cost and programmatic and is divided into four sections. The first section gives illustrations of the SPS reference satellite and rectenna concept, and an overall scenario for SPS space transportation involvement. The second section presents SPS program plans for the implementation of PHASE C/D activities. These plans describe SPS program schedules and networks, critical items of systems evolution/technology development, and the natural resources analysis. The fourth section presents summary comments on the methods and rationale followed in arriving at the results documented. Suggestions are also provided in those areas where further analysis or evaluation will enhance SPS cost and programmatic definitions. G Y

**N79-23487\*** Rockwell International Corp., Downey, Calif. Satellite Systems Div.

### **SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 2, PART 2: SYSTEM ENGINEERING, COST AND PROGRAMMATICS, APPENDICES Final Report**

G. M. Hanley Mar 1979 318 p refs 7 Vol.

(Contract NAS8-32475)

(NASA-CR-161221, SSD-79-0010-2-2-Vol-2-Pt-2-APP) Avail NTIS HC A14/MF A01 CSCL 10B

Appendices for Volume 2 (Part 2) of a seven volume Satellite (SPS) report are presented. The document contains two appendices. The first is a SPS work breakdown structure dictionary. The second gives SPS cost estimating relationships and contains the cost analyses and a description of cost elements that comprise the SPS program. G Y

**N79-23488\*** Rockwell International Corp., Downey, Calif. Satellite Systems Div.

### **SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 4: TRANSPORTATION ANALYSIS Final Report**

G. M. Hanley Mar 1979 268 p refs 7 Vol.

(Contract NAS8-32475)

(NASA-CR-161222, SSD-79-0010-4-Vol-4) Avail NTIS HC A12/MF A01 CSCL 10B

Volume 4 of a seven volume Satellite Power Systems (SPS) is presented. This volume is divided into the following sections: (1) transportation systems elements; (2) transportation systems requirements; (3) heavy lift launch vehicles (HLLV); (4) LEO-GEO transportation; (5) on-orbit mobility systems; (6) personnel transfer systems; and (7) cost and programmatic. Three appendices are also provided and they include: horizontal takeoff (single stage to orbit technical summary); HLLV reference vehicle trajectory and trade study data; and electric orbital transfer vehicle sizing. G Y

**N79-23489\*** Rockwell International Corp., Downey, Calif. Satellite Systems Div.

### **SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 7: SYSTEM/SUBSYSTEM REQUIREMENTS DATA BOOK Final Report**

G. M. Hanley Mar 1979 118 p refs 7 Vol.

(Contract NAS8-32475)

(NASA-CR-161223, SSD-79-0010-7-Vol-7) Avail NTIS HC A06/MF A01 CSCL 10B

Volume 7 of the Satellite Power Systems (SPS) Concept Definition Study final report summarizes the basic requirements

used as a guide to systems analysis and is a basis for the selection of candidate SPS point design(s). Initially, these collected data reflected the level of definition resulting from the evaluation of a broad spectrum of SPS concepts. As the various concepts matured these requirements were updated to reflect the requirements identified for the projected satellite system/subsystem point design(s). The identified subsystem/systems requirements are defined, and where appropriate, recommendations for alternate approaches which may represent improved design features are presented. A more detailed discussion of the selected point design(s) will be found in Volume 2 of this report. G Y

**N79-23492\*** Ketin (Allan D.) Economic Consultants, Los Angeles, Calif.

### **SATELLITE POWER SYSTEM (SPS) RESOURCE REQUIREMENTS (CRITICAL MATERIALS, ENERGY AND LAND)**

Allan D. Ketin Oct 1978 126 p refs Sponsored by NASA and DOE Prepared for PRC Energy Analysis Co.

(Contract EG-77-C-01-4024)

(NASA-CR-158680, HCP/R-4024-02) Avail NTIS HC A07/MF A01 CSCL 10B

The resource impacts of the proposed satellite power system are evaluated. Three classes of resource impacts are considered separately: critical materials, energy, and land use. The analysis focuses on the requirements associated with the annual development of two five-gigawatt satellites and the associated receiving facilities. M M M

### **N79-23496\*** PRC Energy Analysis Co., McLean, Va. **POTENTIAL OF LASER FOR SPS POWER TRANSMISSION**

Claud N. Bain Oct 1978 111 p refs Sponsored by NASA and DOE

(Contract EG-77-C-01-4024)

(NASA-CR-157432, HCP/R-4024-07) Avail NTIS HC A06/MF A01 CSCL 10B

Research on the feasibility of using a laser subsystem as an additional option for the transmission of the satellite power system (STS) power is presented. Current laser work and predictions for future laser performance provide a level of confidence that the development of a laser power transmission system is technologically feasible in the time frame required to develop the SPS. There are significant economic advantages in lower ground distribution costs and a reduction of more than two orders of magnitude in real estate requirements for ground based receiving/conversion sites. M M M

### **N79-23499\*** PRC Energy Analysis Co., McLean, Va. **SATELLITE POWER SYSTEM (SPS) MAPPING OF EXCLUSION AREAS FOR RECTENNA SITES**

James B. Blackburn, Jr. and Bill A. Bavinger Oct 1978 116 p refs Sponsored by NASA and DOE

(Contract EG-77-C-01-4024)

(NASA-CR-157435, HCP/R-4024-10) Avail NTIS HC A06/MF A01 CSCL 10B

The areas of the United States that were not available as potential sites for receiving antennas that are an integral part of the Satellite Power System concept are presented. Thirty-six variables with the potential to exclude the rectenna were mapped and coded in a computer. Some of these variables exclude a rectenna from locating within the area of its spatial influence, and other variables potentially exclude the rectenna. These maps of variables were assembled from existing data and were mapped on a grid system. M M M

### **N79-23500\*** PRC Energy Analysis Co., McLean, Va. **SATELLITE POWER SYSTEM (SPS) MILITARY IMPLICATIONS**

Claud N. Bain Oct 1978 49 p refs Sponsored by NASA and DOE

(Contract EG-77-C-01-4024)  
(NASA-CR-157438, HCP/R-4024-11) Avail NTIS  
HC A03/MF A01 CSCL 10B

The military implications of the reference satellite power system (SPS) were examined as well as important military related study tasks. Primary areas of investigation were the potential of the SPS as a weapon, for supporting U.S. military preparedness, and for affecting international relations. In addition, the SPS's relative vulnerability to overt military action, terrorist attacks, and sabotage was considered. MMM

**N79-23502\*** PRC Energy Analysis Co., McLean, Va.  
**SATELLITE POWER SYSTEM (SPS) FINANCIAL MANAGEMENT SCENARIOS**

Herbert E. Kieroff Oct 1978 65 p refs Sponsored by NASA and DOE

(Contract EG-77-C-01-4024)  
(NASA-CR-157438, HCP/R-4024-13) Avail NTIS  
HC A04/MF A01 CSCL 10B

The factors involved in the evaluation of the Satellite Power System's (SPS) feasibility and in SPS financing and management are presented. Areas for further research are also enumerated. MMM

**N79-24024\*** Parker (Lee W.), Inc., Concord, Mass.  
**PLASMA SHEATH EFFECTS AND VOLTAGE DISTRIBUTIONS OF LARGE HIGH-POWER SATELLITE SOLAR ARRAYS**

Lee W. Parker In NASA Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 341-357 refs

Avail NTIS HC A99/MF A01 CSCL 22B

Knowledge of the floating voltage configuration of a large array in orbit is needed in order to estimate various plasma-interaction effects. The equilibrium configuration of array voltages relative to space depends on the sheath structure. The latter dependence for an exposed array is examined in the light of two finite-sheath effects. One effect is that electron currents may be seriously underestimated. The other is that a potential barrier for electrons can occur, restricting electron currents. A conducting surface is assumed on the basis of a conductivity argument. Finite-sheath effects are investigated. The results of assuming thin-sheath and thick-sheath limits on the floating configuration of a linearly connected array are studied. Sheath thickness and parasitic power leakage are estimated. Numerically computed fields using a 3-D code are displayed in the thick-sheath limit. G Y

**N79-24026\*** National Aeronautics and Space Administration  
Marshall Space Flight Center, Huntsville, Ala.  
**MAGNETIC SHIELDING OF LARGE HIGH-POWER SATELLITE SOLAR ARRAYS USING INTERNAL CURRENTS**

Lee W. Parker (Parker (Lee W.), Inc., Concord, Mass.) and William A. Olan In NASA Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 376-387 refs

Avail NTIS HC A99/MF A01 CSCL 22B

Present concepts for solar power satellites involve dimensions up to tens of kilometers and operating internal currents up to hundreds of kiloamperes. A question addressed is whether the local magnetic fields generated by these strong currents during normal operation can shield the array against impacts by plasma ions and electrons (and from thruster plasmas) which can cause possible losses such as power leakage and surface erosion. One of several prototype concepts was modeled by a long narrow rectangular panel 2 km wide and 20 km long. The currents flow in a parallel across the narrow dimension (sheet current) and along the edge (wire currents). The wire currents accumulate from zero to 100 kA and are the dominant sources. The magnetic field is approximated analytically. The equations of

motion for charged particles in this magnetic field are analyzed. The ion and electron fluxes at points on the surface are represented analytically for monoenergetic distributions and are evaluated.

G Y

**N79-24028\*** Rice Univ., Houston, Tex. Dept. of Space Physics and Astronomy  
**SPACE ENVIRONMENTAL EFFECTS AND THE SOLAR POWER SATELLITE**

John W. Freeman, David Cooke, and Patricia Roff In NASA Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 408-418 refs

Avail NTIS HC A99/MF A01 CSCL 22B

Some preliminary findings regarding the interactions between the space plasma at GEO and the Marshall Space Flight Center January 1978 baseline Satellite Power Systems (SPS) design are summarized. These include the following: (1) the parasitic load will be dominated by photoelectrons and will amount to about 34 MW; (2) material of higher conductivity than kapton should be used for the solar reflector substrate and the solar cell blanket support material; (3) the satellite structure and solar reflector should be tied electrically to midpoint voltage of each solar cell array; and (4) tests should be run on the proposed solar cell cover glass material (synthetic sapphire) to determine if breakdown is expected. G Y

**N79-24436\*** National Aeronautics and Space Administration  
Washington, D. C.

**PRELIMINARY ENVIRONMENTAL ASSESSMENT FOR THE SATELLITE POWER SYSTEM (SPS) VOLUME 2 DETAILED ASSESSMENT**

Oct 1978 175 p refs Prepared in cooperation with DOE, Washington, D. C. 2 Vol

(NASA TM 80355, DOE/ER-0021/2) Avail NTIS  
HC A08/MF A01 CSCL 10B

Volume 2 provides a preliminary assessment of the impact of the Satellite Power System (SPS) on the environment in a technically detailed format more suitable for peer review than the executive summary of Vol 1. It serves to integrate and assimilate information that has appeared in documents referenced herein and to focus on issues that are purely environmental. It discloses the state-of-knowledge as perceived from recently completed DOE sponsored studies and defines prospective research and study programs that can advance the state-of-knowledge and provide an expanded data base for use in on-going environmental research for 1980. Alternatives for research that may be required in order to achieve this advancement are also discussed. Author

**N79-26213\*** Aerospace Corp., El Segundo, Calif. Space Sciences Lab

**ENVIRONMENTAL FACTORS OF POWER SATELLITES Interim Report**

Yam T. Chiu and Barbara K. Ching 8 Jul 1979 49 p refs (Contract F04701 78 C 0079)

(SAMSO-TR 79-66, TR G079(4960 04) 5) Avail NTIS  
HC A03/MF A01

All presently known factors in the construction and operation of the proposed solar power satellite which may produce effects on the environment from ground level to beyond the magnetopause are reviewed. Characteristics of the propulsion system exhausts of the space segment, the microwave beam, the satellite physical structure, and the WLLV launch and landing activities are described. A R H

**N79-29212\*** Committee on Science and Technology (U.S. House)

**SOLAR POWER SATELLITE**

Washington GPO 1979 344 p refs Hearings before the Subcomm. on Space Sci. and Applications of the Comm. on Sci. and Technol., 96th Congr., 1st Sess., 28-30 Mar 1979

(GPO-45-997) Avail Subcomm. on Space Sci. and Applications



## 10 SOLAR POWER SATELLITE SYSTEM

A technology verification program to enable the resolution of the technical, environmental, and economic issues surrounding the concept of a solar power satellite is considered. Specific issues discussed include: biological and ionospheric impacts, radio frequency interference, and research on the space segment of the microwave power system to ensure technical and economic feasibility. J M S

**N79-30726** Committee on Energy and Natural Resources (U.S. Senate)

### **SOLAR POWER SATELLITE RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAM ACT OF 1978**

Washington GPO 1978 270 p refs Hearing on S 2860 and H.R. 12505 before the Subcomm. on Energy and Natural Resources, 95th Congr., 2d Sess., 14 Aug 1978

(GPO 35-994, Publ 95-166) Avail: Subcomm. on Energy Res. and Development

Satellite solar energy conversion transmission to earth to generate electricity for domestic purposes is studied. A space orbiting mirror system designed to provide continuous and slightly concentrated reflected solar energy to selected solar conversion sites is examined. Development of this system is discussed through economic viability, design feasibility, and energy storage and conversion techniques. A W H

**N79-30730\*** European Space Agency, Paris (France)

### **PHOTOVOLTAIC GENERATORS IN SPACE**

K. Bogus, ed and T. D. Guyenne, ed. Nov 1978 344 p refs Proc. of 1st European Symp. on Photovoltaic Generators in Space, Noordwijk, Neth., 11-13 Sep. 1978

(SP-140) Avail: NTIS HC A15/MF A01

A series of lectures was given including, as main topics, solar cell technology, module and blanket technology, design analysis and verification, interface problems, evolution of photovoltaics, solar power satellites, solar arrays, and test results as well as flight data.

### **N79-30750\*** Boeing Aerospace Co., Seattle, Wash. **SOLAR POWER SATELLITES: THE ENGINEERING CHALLENGES**

G. R. Woodcock. In: ESA Photovoltaic Generators in Space. Nov 1978 p 129-147

(Contract NAS9-15196)

Avail: NTIS HC A15/MF A01

Certain elements of solar power satellite design and system engineering studies are reviewed analyzing solar power satellites as a potential baseload electric power source. The complete system concept includes not only the satellites and their ground stations, but also the space transportation for delivery of the satellites, piece by piece, into space, and the factories for their construction in space. Issues related to carrying the solar power satellite concept from the present design study phase through implementation of actual hardware are considered. The first issue category is environmental aspects of the SPS systems. The second category of issues is the technology risks associated with achieving the necessary component and subsystem performances. The third category includes the engineering issues associated with carrying out such a large scale project. The fourth issue category is financial: the funding required to bring such a project into being and the costs of the satellites and resulting cost of the power produced as compared to potential alternative energy sources. Author (ESA)

### **N79-30751\*** European Space Agency, Noordwijk (Netherlands) **INTERFACE PROBLEMS ON AN SPS SOLAR ARRAY BLANKET**

D. Kassing. In: ESA Photovoltaic Generators in Space. Nov 1978 p 149-159 refs

Avail: NTIS HC A15/MF A01

Starting from a survey of proposed photovoltaic Solar Power Satellite (SPS) configurations, the design trend of solar arrays applicable in an SPS development program is sketched out indicating physical and other interface problems of the solar array sub-system with adjacent sub-systems and the space environment. The nature of research and development program on SPS solar cell blankets is discussed and a list containing potential study tasks for the near future is presented. The objective is to identify, from a systems engineering of view, the limiting conditions and interface problems associated with the development and operation of large solar generator blankets to be used in SPS systems and to discuss the nature of the supporting research and technology program aimed at solving the mentioned interface problems. Author (ESA)

**N79-30752\*** Technische Univ. Berlin (West Germany) Inst. fuer Luft und Raumfahrt

### **MOSGEN: A POTENTIAL EUROPEAN CONTRIBUTION IN DEVELOPING LARGE SOLAR GENERATORS SUITABLE FOR GROWING POWER LEVELS UP TO SPS SYSTEMS**

J. Ruth and W. Westphal. In: ESA Photovoltaic Generators in Space. Nov 1978 p 161-166 refs

Avail: NTIS HC A15/MF A01

A potential development program for large solar generators in space, which seems to be suited especially for European needs is discussed. The cost of production and transport have to be reduced to a minimum by constructive and technological steps so that they become competitive power plants. The concept of a modular collector system represents one step in that direction. The modular philosophy is easily transferable to different sizes and applications of solar generators leading to solar power satellites. An evolutionary strategy of development helps to provide high economical benefit of the modular attempt compared to nonmodular separately developed alternatives. This strategy means governing the development process by feed back dynamic optimization. Author (ESA)

### **N79-31251\*** PRC Energy Analysis Co., McLean, Va. **SATELLITE POWER SYSTEM (SPS) RESOURCE REQUIREMENTS (CRITICAL MATERIALS, ENERGY, AND LAND)**

Allan D. Kotin (Kotin (Allan D.) Economic Consultants, Los Angeles, Calif.) Oct 1978 126 p refs. Sponsored in cooperation with NASA

(Contract EG-77-C-01-4024)

(NASA-CR-162310, SE-4024 T1)

Avail: NTIS

HC A07/MF A01 CSCI 10A

The resource impacts of the proposed satellite power system (SPS) were reviewed. Three classes of resource impacts were considered separately: critical materials, energy and land use. The analysis focused on the requirements associated with the annual development of two five-gigawatt satellites and the associated receiving facilities. DOE

### **N79-31764\*** Chicago Univ., Ill. Enrico Fermi Inst. **WINSTON SOLAR CONCENTRATORS AND EVALUATION SUPPORT. PHASE 2: NON-IMAGING CONCENTRATORS FOR SPACE APPLICATIONS. Final Report, Oct. 1977 - Jul. 1978**

Roland Winston, Joseph O'Gallagher, and Peretz Greenman. 28 Aug 1978 81 p refs. Prepared for JPL

(Contract JPL 954563)

(NASA-CR-162279) Avail: NTIS HC A05/MF A01 CSCI 10A

A 4.67X, plus or minus 5 deg. compound parabolic concentrator (CPC) for a large photovoltaic array in space was analyzed. The design was demonstrated to be effective in achieving a net power gain which can be varied from more than a factor of 3 down to approximately unity. A method for reducing nonuniformities in illumination to a given desired level was found. The effectiveness of this method, which involves the introduction of a degree of non-specularity in the reflector surface, was confirmed.

by direct measurements with prepared foil reflectors in a CPC in terrestrial sunshine as well as by computer ray tracing. Further ray tracing confirms that the CPC design is extremely tolerant to pointing and alignment errors, minor distortions, etc. A two stage non-imaging design was shown, by preliminary measurements and analysis, to provide both the desired angular tolerance and the required degree of intensity uniformity if higher concentrations (4X, 10X) are necessary. Author

**N79-32641\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**THE NASA LEWIS RESEARCH CENTER PROGRAM IN SPACE SOLAR CELL RESEARCH AND TECHNOLOGY**

Henry W. Brandhorst, Jr. In *its* Solar Cell High Efficiency and Radiation Damage. 1979 Aug 1979 p 1-4

Avail NTIS HC A13/MF A01 CSCL 10A

Progress in space solar cell research and technology is reported. An 18 percent AMO efficient silicon solar cell, reduction in the radiation damage suffered by silicon solar cells in space and high efficiency wrap around contact and thin (50 micrometer) coplanar back contact silicon cells are among the topics discussed. Reduction in the cost of silicon cells for space use, cost effective GaAs solar cells, the feasibility of 30 percent AMO solar energy conversion and reliable encapsulants for space blankets are also considered. J M S

**N79-32642\*** Air Force Aero Propulsion Lab, Wright-Patterson AFB, Ohio

**SOLAR PHOTOVOLTAIC RESEARCH AND DEVELOPMENT PROGRAM OF THE AIR FORCE AERO PROPULSION LABORATORY**

Joseph Wise In *NASA Lewis Res. Center Solar Cell High Efficiency and Radiation Damage*. 1979 Aug 1979 p 5-8

Avail NTIS HC A13/MF A01 CSCL 10A

Progress is reported in the following areas: laser weapon effects, solar silicon solar cell concepts, and high voltage hardened, high power system technology. Emphasis is placed on solar cells with increased energy conversion efficiency and radiation resistance characteristics for application to satellite power systems. J M S

**N79-32643\*** Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena  
**THE JPL SPACE PHOTOVOLTAIC PROGRAM**

John A. Scott-Monck In *NASA Lewis Res. Center Solar Cell High Efficiency and Radiation Damage*. 1979 Aug 1979 p 9-12 (Contract NAS7-100)

Avail NTIS HC A13/MF A01 CSCL 10A

The development of energy efficient solar cells for space applications is discussed. The electrical performance of solar cells as a function of temperature and solar intensity and the influence of radiation and subsequent thermal annealing on the electrical behavior of cells are among the factors studied. Progress in GaAs solar cell development is reported with emphasis on improvement of output power and radiation resistance to demonstrate a solar cell array to meet the specific power and stability requirements of solar power satellites. J M S

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# 11 GENERAL

includes either state-of-the-art or advanced technology which may apply to Large Space Systems and does not fit within the previous nine categories. Shuttle payload requirements, on-board requirements, data rates, and shuttle interfaces, and publications of conferences, seminars, and workshops will be covered in this area.

**A79-24060** The dimensioning of complex steel members in the range of endurance strength and fatigue life (Dimensionierung komplizierter Bauteile aus Stahl im Bereich der Zeit- und Dauerfestigkeit). D. R. Lang (Daimler-Benz AG, Stuttgart, West Germany). *Zeitschrift für Werkstofftechnik*, vol. 10, Jan. 1979, p. 24-29. 27 refs. In German.

The considered dimensioning concept makes a distinction between actual and admissible stresses. The concept was developed on the basis of an evaluation of approximately 1600 individual measurements reported in various publications. The requirements regarding a practical implementation of the dimensioning concept are taken into account by basing the procedure on the static strength data which are already known in the design stage. Attention is given to a regression formula for the determination of the long-term alternating-strength stress for unnotched specimens, the long-term alternating-strength stress of notched members, aspects of medium-stress dependence, the effect of boundary layer strengthening, endurance strength, and application examples, including a gear wheel, and a crankshaft. G. R.

**A79-24021** Anomalous intensity ratios of the resonance to intercombination lines of He-like ions in Nd- and CO<sub>2</sub>-laser produced plasma. V. A. Boiko, A. Iu. Chugunov, A. Ia. Farnov, S. A. Pikuz, I. Iu. Skobelev, A. V. Vinogradov, and E. A. Iukov (Akademii Nauk SSSR, Fizicheskii Institut, Moscow, USSR). *Journal of Physics B: Atomic and Molecular Physics*, vol. 12, Jan. 28, 1979, p. 213-220. 25 refs.

Anomalous small values of the intensity ratio  $\alpha$  of resonance and intercombination lines of He-like ions have been observed in Nd- and CO<sub>2</sub>-laser produced plasmas. The values of  $\alpha$  obtained are explained via calculations using a non-stationary ionization model for the plasma (overheated, for CO<sub>2</sub>-laser plasma, and supercooled, for expanding Nd-laser plasma). The measurements of the intensity ratio may be used to obtain information on the relative concentrations of H-, He-, and Li-like ions in the plasma. The results obtained allow one to answer the questions: when must the non-stationary character of the plasma ionization state be taken into account for the observed spectra to be interpreted correctly and when can one use more simple stationary models for the plasma concerned. (Author)

**A79-30782** A method of controlling orbits of geostationary satellites with minimum fuel consumption. K. Takahashi. *Radio Research Laboratories, Journal*, vol. 25, July-Nov. 1978, p. 247-259.

The orbital angular velocity of a stationary satellite is considered to express the perturbation on an orbit of the satellite, and to draw the conclusion that the minimum variation in direction of this velocity agrees with the minimum fuel consumption to maintain a stationary satellite within allocated bounds. The directional variation of the orbital angular velocity is kept minimum by maintaining the ascending node of the orbit in about the direction of the vernal equinox. The direction of the ascending node with minimum fuel consumption to maintain the orbit is given over 18.6 year nodal period of the moon, over which period the inclination variation of the orbit and the angular speed proportional to the necessary amount

of fuel to maintain the orbit  $\alpha$  is also given. The method in this paper is applicable to geostationary communication satellites, UHF broadcasting satellites, solar power satellites etc. (Author)

**A79-33992** SOLARES - A new hope for solar energy. K. W. Billman, W. P. Gilbreath (NASA, Ames Research Center, Moffett Field, Calif.), and S. W. Bowen. In: *Alternative energy sources. Proceedings of the Miami International Conference, Miami Beach, Fla., December 5-7, 1977. Volume 1.* Washington, D.C., Hemisphere Publishing Corp., 1978, p. 233-255. 13 refs.

A system of orbiting reflectors, SOLARES, has been studied as a possible means of reducing the diurnal variation and enhancing the average intensity of sunlight with a space system of minimum mass and complexity. The key impact that such a system makes on the economic viability of solar farming and other solar applications is demonstrated. The system is compatible with incremental implementation and continual expansion to meet the world's power needs. Key technology, environmental, and economic issues and payoffs are identified. SOLARES appears to be economically superior to other advanced, and even competitive with conventional, energy systems and could be scaled to completely abate our fossil fuel usage for power generation. Development of the terrestrial solar conversion technique, optimized for this new artificial source of solar radiation, yet remains. (Author)

**A79-34701** Conference on Advanced Technology for Future Space Systems. Hampton, Va., May 8-10, 1979. Technical Papers. Conference sponsored by the American Institute of Aeronautics and Astronautics and NASA. New York: American Institute of Aeronautics and Astronautics, Inc., 1979. 605 p. Members, \$60; nonmembers, \$70.

Propulsion systems for spacecraft, satellite communications technology, the design of large light weight structure for assembly in space, electronics, and information processing for spacecraft, and self diagnostic, fault tolerant controls based on high memory and processing capabilities are discussed. Topics of the papers include: the design of large delta wings for earth-to-orbit transport; dual fuel propulsion units; magnetoplasmadynamic thrusters; heating rates on blunt-nosed bodies at various angles of attack; remote manipulators for space assembly tasks; solar electric propulsion for planetary missions; deployable space platforms with multiple payloads; the design of large offset fed antennas; a nonlinear stress-strain relationship for metallic meshes; and adaptive sensors for spacecraft. J. M. B.

**A79-34705** A space-based orbital transfer vehicle: Bridge to the future. J. J. Reider and D. G. Eide (NASA, Langley Research Center, Vehicle Analysis Branch, Hampton, Va.). In: *Conference on Advanced Technology for Future Space Systems*. Hampton, Va., May 8-10, 1979. Technical Papers. New York: American Institute of Aeronautics and Astronautics, Inc., 1979. p. 30-38. 8 refs. (AIAA 79-0865)

A comparison is made between a space-based and earth-based orbital transfer vehicle (OTV) for use in the Shuttle era and beyond. The space-based vehicle alleviates the limited capability inherent in an earth-based OTV whose design is constrained by a particular launch vehicle. Several sizes of space-based OTVs were generated and compared with an earth-based system for a number of mission scenarios with varying types and levels of traffic. The space-based OTVs showed substantial cost savings for each scenario, with the smallest space-based vehicle showing the largest saving. The space-based OTV retains the cost advantage even if the number of missions or the Shuttle cost per flight is drastically reduced. (Author)

**A79-34728 \*** Preliminary design for a space based orbital transfer vehicle. I. O. MacConochie, J. J. Rehder (NASA, Langley Research Center, Space Systems Div., Hampton, Va.), and E. P. Brien (Kertron International, Inc., Hampton, Va.) In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 220-224. 7 refs. (AIAA 79-0897)

A space-based orbital transfer vehicle has been sized for a 50-metric-ton payload delivery from low-earth-orbit to a geosynchronous orbit. Space basing effected substantial reductions in cryogenic insulation, tank, and body structure. The tank and body structural masses are shown to be lower for space basing because of the larger difference in acceleration loads between the on-orbit case (0.2 g's) and delivery (3.0 g's), the latter applying to ground-based vehicles which are delivered to orbit fully loaded with propellants. Insulation masses are lower because of the absence of an atmosphere and the attendant heat transfer losses. Insulation systems masses are also reduced because of the elimination of the problem of liquefaction and freezing of moisture on the tanks. (Author)

**A79-34739 \*** Synchronous orbit power technology needs. L. W. Shifer, Jr. (NASA, Goddard Space Flight Center, Power Applications Branch, Greenbelt, Md.) and W. J. Billerbeck (COMSAT Laboratories, Clarksburg, Md.) In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 315-323. 16 refs. Research supported by COMSAT Laboratories and NASA. (AIAA 79-0916)

An attempt is made to define the needs for future geosynchronous spacecraft power subsystem components, including power generation, energy storage, and power processing. Three projected models (a mission model, an orbit transfer vehicle model, and a mass model) for power subsystem components are used to define power requirements and mass limitations for future spacecraft. Based upon these models, the power subsystems for a 10-kW, 10-year life, dedicated spacecraft and for a 20-kW, 20-year life multimission platform are analyzed to establish power density requirements for orbit transfer vehicles. Comparison of these requirements to state-of-the-art (Intelsat 5) design values shows that major improvements, by a factor of 2 or more, are needed to accomplish the near term missions. B.J.

**A79-34775 \*** Large space system - Charged particle environment interaction technology. N. J. Stevens, J. C. Roche, and N. T. Grier (NASA, Lewis Research Center, Cleveland, Ohio). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, 21 p. 31 refs. (AIAA 79-0913)

Large high-voltage space power systems proposed for future applications in both low earth orbit and geosynchronous altitudes must operate in the space charged-particle environment with possible interactions between this environment and the high-voltage surfaces. The paper reviews the ground experimental work to provide indicators for the interactions that could exist in the space power system. A preliminary analytical model of a large space power system is constructed using the existing NASA Charging Analyzer Program, and its performance in geosynchronous orbit is evaluated. The analytical results are used to illustrate the regions where detrimental interactions could exist and to establish areas where future technology is required. S.D.

**A79-34860 \*** The future United States space program. Proceedings of the Twenty-fifth Anniversary Conference, Houston, Tex., October 30-November 2, 1978. Parts 1 & 2. Conference

sponsored by the American Astronautical Society, Boeing Co., General Electric Co., IBM Corp., Lockheed Electronics Co., Northrop Services, Inc., Technology, Inc., and NASA. Edited by R. S. Johnston (NASA, Johnson Space Center, Houston, Tex.), A. Naumann, Jr. (Lockheed Electronics Co., Inc., Plainfield, N.J.), and C. W. G. Fulcher (General Electric Co., Fairfield, Conn.). San Diego, Calif., American Astronautical Society (Advances in the Astronautical Sciences, Volume 38, Pts. 1 & 2). Univelt, Inc., 1979, Pt. 1, 442 p.; pt. 2, 432 p. Price of two parts, \$80.

Space Shuttle guidance problems, solar power satellites, space law, satellite communications, space medicine, and engineering of large space systems are discussed. Topics of the papers include biological experiments designed for the Space Shuttle, an optimized guidance law for Space Shuttle re-entry, aircraft propulsion based on laser energy, industrial materials available in the lunar soil, health program for a solar power satellite construction team, closed life support systems for large habitats in space, the advantages of a manned mission to Mars, the interpretation of radar imagery of Venus, a cost analysis for the satellite power system, and the geological history of Mars. J.M.B.

**A79-34865** Future programs in space. J. A. Snow (U.S. Department of Energy, Office of Energy Research, Washington, D.C.). In: The future United States space program, Proceedings of the Twenty-fifth Anniversary Conference, Houston, Tex., October 30-November 2, 1978. Part 2. San Diego, Calif., American Astronautical Society, Univelt, Inc., 1979, p. 689-703. (AAS 78-180)

There are a variety of areas in which space has the potential for contributing to the future well-being of the United States and the world. It has been evident - even before the current intense focus on energy problems - that remote sensing from aircraft and spacecraft can make significant contributions to energy, as related to exploration, extraction, power plant siting, environmental monitoring and assessment, and applications for developing nations. A discussion of requirements for implementation of satellite power systems reveals that there is a potential future for a vastly abundant supply of energy through the satellite power system. The U.S. civil space policy is also examined. S.D.

**A79-38060 \*** Externally pumped Rankine cycle thermal transport devices. R. J. Hannemann (Digital Equipment Corp., Maynard, Mass.). American Institute of Aeronautics and Astronautics, Thermophysics Conference, 14th, Orlando, Fla., June 4-6, 1979, Paper 79-1091. 7 p. 10 refs.

An attempt is made to document a brief feasibility study of the use of externally pumped heat pipes (EPHPs) for the thermal control of large structures in space. The discussion is limited to a simplified EPHP analysis, idealized performance for space structure isothermalization, and potential terrestrial applications. If the source and sink have finite thermal capacities, the EPHP will tend to equalize their temperatures, which is the desired goal for eliminating thermal stresses in large structures. The EPHP offers significantly improved thermal performance if one is willing to pay the price of supplying a small amount of pumping power. Terrestrial uses, such as thermal transport in solar energy systems or electronic equipment cooling, are potentially even more significant than space application. S.D.

**A79-44248 \*** Planning Space Shuttle's maiden voyage. M. S. Malkin and R. F. Freitag (NASA, Washington, D.C.). IEEE Spectrum, vol. 16, July 1979, p. 42-50.

NASA's first Space Shuttle, Columbia, whose technological advances include a space laboratory, navigational and communication satellites, and planetary explorers, is examined, and the first few flights, scheduled for 1980, are described. The Shuttle employs an

all-digital, all-electronic, computer-operated avionics system. The on-board data processing and software subsystem, encompassing five computers (four online and one backup), a data-bus network, bus terminals, and software, is analyzed in detail. Attention is given to the basic structure of the Orbiter (37.19 m in length and 23.77 m wingspan), its main engines, and the payload and cargo capacities (29,500 kg). A two-step program that could increase the power and duration of spaceflights is presented. The first step is the creation of a power extension package, using solar arrays, generating electricity to extend the basic five-day flight to 20 days, while the second step uses the same design to create a 25-kW power model capable of providing energy for a 50-day flight. Plans for construction of a manned space construction base and a larger power platform of 250 kW are also presented. C.F.W.

**A79-53255 \*** **Orbit transfer operations for the Space Shuttle era.** H. P. Davis (NASA, Johnson Space Center, Houston, Tex.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-29, 20 p., 15 refs.*

Orbit transfer operations are reviewed relative to the objectives, operational factors, and crew model concepts of future mission requirements. The review is based on studies presently underway and on projected needs and goals of the Space Shuttle era. Numerous tradeoff studies and further analyses are needed before the best form of the manned geostationary vehicle becomes fixed. However, the Shuttle can provide the necessary low-orbit logistics service for dispatching manned geostationary missions on as frequent a schedule as will be needed to serve the advanced geostationary satellites of the near future. S.D.

**A79-53256** **Orbit transfer needs of the late 1980s and the 1990s.** M. G. Wolfe and R. A. Martunian (Aerospace Corp., El Segundo, Calif.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-30, 15 p., 22 refs.*

This paper presents future orbit transfer requirements and examples of advanced revolutionary spacecraft. Early high-energy payloads will be transferred from Shuttle orbit to higher orbit with the expendable IUS or the Spinning Solid Upper Stage. Later the advanced payloads will require a more sophisticated Orbit Transfer Vehicle (OTV) with higher payload capability and orbital operational flexibility. Orbit transfer requirements will extend from synchronous equatorial to planetary orbits, and the advanced spacecraft will be transferred from Shuttle orbit to high earth orbit in the form of separate modules. In addition to transferring primary mission payloads, the OTV will perform many support functions, such as rendezvous and docking, orbital maneuvering, servicing, and the transfer of man. Support facilities, such as power modules and space assembly construction facilities may become candidate OTV payloads, and the additional requirements imposed on the OTV are considered along with those imposed by the primary missions. A.T.

**A79-53356** **Space to benefit mankind - 1980 to 2000.** C. L. Gould (Rockwell International Corp., Satellite Systems Div., Downey, Calif.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-206, 22 p., 13 refs.*

This paper deals with the use of space for major, tangible benefits with commercial and social value over the next three decades. A background of future needs and trends is presented, and opportunities for applying space to these needs are listed. An overall suggested space industrialization program is presented, and the benefits of such a program are shown. (Author)

**A79-53454 \*** **Space telecommunications at present and in future.** J. Buuk. *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-151L 04, 8 p.*

The paper presents information on space telecommunications, which includes a brief summary of the development of the last twenty years, as well as some of the principles on which the Space Treaty of 1967 is based. Attention is given to the agenda of the World Administrative Radio Conference, to be held in latter part of 1979. Topics that will be discussed are examined, including geostationary satellite orbit, broadcasting satellite service, telecommunications satellite systems, earth exploration satellites, solar power satellites, and the search for extraterrestrial intelligence. C.F.W.

**N79-22188\*#** **National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio. LARGE SPACE SYSTEM: CHARGED PARTICLE ENVIRONMENT INTERACTION TECHNOLOGY**

N. John Stevens, James C. Roche, and Norman T. Grer. 1979. 23 p. refs. Presented at the Conf. on Advanced Technol. for Future Space Systems, Hampton, Va. 8-11 May 1979, sponsored by AIAA. (NASA-TM-79156, E-012) Avail. NTIS HC A02/MF A01 CSCL 22B

Large, high voltage space power systems are proposed for future space missions. These systems must operate in the charged particle environment of space and interactions between this environment and the high voltage surfaces are possible. Ground simulation testing indicated that dielectric surfaces that usually surround biased conductors can influence these interactions. For positive voltages greater than 100 volts, it has been found that the dielectrics contribute to the current collection area. For negative voltages greater than 500 volts, the data indicates that the dielectrics contribute to discharges. A large, high-voltage power system operating in geosynchronous orbit was analyzed. Results of this analysis indicate that very strong electric fields exist in these power systems. S.E.S.

**N79-22539\*#** **National Aeronautics and Space Administration Lyndon B. Johnson Space Center, Houston, Tex.**

**THE 13TH AEROSPACE MECHANISMS SYMPOSIUM**

Aleck C. Bond. 1979. 300 p. refs. Proc. of Symp. held at Houston, Tex. 26-27 Apr. 1979. (NASA-CP 2081, S-496) Avail. NTIS HC A13/MF A01 CSCL 13I

Technological areas covered include propulsion, motion compensation, instrument pointing and adjustment, centrifuge testing, bearing design, vehicle braking, and cargo handling. Devices for satellite, missile, and hypersonic wind-tunnel applications, space shuttle mechanical and thermal protection systems, and techniques for building large space structures are described. In addition, a fluid drop injector device for a Spacelab experiment, a helical grip for cable cars, and applications of rare earth permanent magnets are discussed.

**N79-23666\*#** **Hamilton Standard, Hartford, Conn. CONCEPT DEFINITION FOR AN EXTENDED DURATION ORBITER ECLSS**

H. Brose. Sep. 1977. 244 p. (Contract NAS9-14782) (NASA-CR 160164) Avail. NTIS HC A11/MF A01 CSCL 06K

Extending the seven-day Shuttle Orbiter baseline mission requires an evaluation of the Environmental Control and Life Support (ECLS) System in order to determine those changes necessary or desirable so that the Orbiter payload capability will not be seriously compromised. The ECLS requirements and subsystem options for extended duration Orbiter missions are defined. Each major ECLS subsystem was examined, and potential methods of extending the mission capability were studied. The mission evaluated most extensively for this effort was a 30 day mission with a crew size of seven men. However, missions up to 90 days duration with crew sizes of three to ten men were also examined. G.V.



## 11 GENERAL

**N79 24001\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### SPACECRAFT CHARGING TECHNOLOGY, 1978

1979 908 p refs. Conf. held at Colorado Springs, Colo., 31 Oct - 2 Nov 1978, sponsored by NASA and AFGL (NASA CP 2071, AFGL TR 79-0082) Avail NTIS HC A99/MF A01 CSCL 22B

The interaction of the aerospace environment with spacecraft surfaces and onboard, high voltage spacecraft systems operating over a wide range of altitudes from low Earth orbit to geosynchronous orbit is considered. Emphasis is placed on control of spacecraft electric potential. Electron and ion beams, plasma neutralizers material selection, and magnetic shielding are among the topics discussed.

**N79 24019\*** Air Force Geophysics Lab., Hanscom AFB, Mass.  
**THE CALCULATION OF SPACECRAFT POTENTIAL: COMPARISON BETWEEN THEORY AND OBSERVATION**  
H B Garrett. In NASA Lewis Res. Center. Spacecraft Charging Technol., 1978 1979 p 239-255 refs

Avail NTIS HC A99/MF A01 CSCL 22B

A simple charge balance model based on the work of DeForest was adapted for the calculation of spacecraft potentials. The model was calibrated with ATS 5 plasma data. Once calibrated the model was used to calculate the time-varying potential that was observed as a spacecraft passes in and out of eclipse. Errors on the order of  $\pm$  or 800 volts were observed over a range of 0 to -10,000 volts. Possible applications of the model to large space structures are discussed. J A M

**N79 24054\*** Spire Corp., Bedford, Mass.  
**A COMBINED SPACECRAFT CHARGING AND PULSED X RAY SIMULATION FACILITY**

Steven H Face, Michael J Nowlan, William R Neal, and William A Sedler. In NASA Lewis Res. Center. Spacecraft Charging Technol., 1978 1979 p 854-867 refs. Sponsored by DNA

Avail NTIS HC A99/MF A01 CSCL 22B

A spacecraft charging simulation facility constructed to investigate the response of satellite materials in a typical geomagnetic substorm environment is described. The conditions simulated include vacuum, solar radiation, and substorm electrons. A nuclear threat environment simulation using a flash X ray generator is combined with the spacecraft charging facility. Results obtained on a solar cell array segment used for a preliminary facility demonstration are presented with a description of the facility. M M M

**N79 25927\*** Committee on Commerce, Science, and Transportation (U S Senate)

### NASA AUTHORIZATION FOR FISCAL YEAR 1980, PART 2

Washington GPO 1979 507 p refs. Hearings on S 357 before the Comm. on Commerce, Sci., and Transportation, 96th Congr., 1st Sess., 21-22 and 28 Feb 1979 (GPO 43 135) Avail. Comm. on Commerce, Sci., and Transportation

Testimony delivered and statements received to justify NASA's budget requests to support program management, research and development, construction of facilities, and other activities are presented. Implications of the civilian space policy, capabilities of the space shuttle, and the status of its main engine are discussed as well as accomplishments in advanced programs related to power systems, space platforms and space transportation systems, and satellite services. A R H

**N79 30093\*** Committee on Commerce, Science, and Transportation (U S Senate)

### NASA AUTHORIZATION FOR FISCAL YEAR 1980, PART 3

Washington GPO 1979 558 p refs. Hearings on S 357 before the Comm. on Commerce, Sci., and Transportation, 96th Congr., 1st Sess., 2, 14-15 Mar., 1 May and 4 Jun 1979 (GPO 44-885) Avail. Comm. on Commerce, Sci., and Transportation

Testimonies, primarily from NASA (National Aeronautics and Space Administration) witnesses, before the Committee on Commerce, Science, and Transportation (United States Senate) are documented. The hearing was held to authorize appropriations to NASA for research and development, construction of facilities, research and program management, and for other purposes for FY-80. G Y

**N79 30267\*** Rockwell International Corp., Downey, Calif. Satellite Systems Div

### SPACE CONSTRUCTION SYSTEMS ANALYSIS STUDY, TASK 3: CONSTRUCTION SYSTEM SHUTTLE INTEGRATION Final Report

Jun 1979 28 p  
(Contract NAS9-15718)  
(NASA-CR-160296) Avail NTIS HC A03/MF A01 CSCL 22A

The implications and impacts deriving upon the orbiter by its utilization as a space construction facility for the selected flight system projects are presented. G Y

**N79 30754\*** Spar Aerospace Products Ltd., Toronto (Ontario), Canada.  
**CANADIAN DEVELOPMENT OF LARGE DEPLOYABLE SOLAR ARRAYS FOR COMMUNICATIONS SPACECRAFT**  
E Outtier, H Borduas, J T Renshall, and S Ahmed (Dept. of Comm., Canada). In ESA Photovoltaic Generators in Space Nov 1978 p 181-192 refs. Sponsored by Canadian Dept. of Comm.

Avail NTIS HC A15/MF A01

Solar array designs that have the potential of cost-effectively satisfying three-axis stabilized geostationary communications satellite power requirements at beginning of life are discussed. The BI-STEM and Astromast deployed 5 and 10 kW beginning of life array designs are examined. To a varying degree the designs were derived from the flight proven Hermes (CTS) array. Except for the Hermes array, all the array designs have the hybrid capability of re-using the spin-phase array segment cells during on-station operation. These arrays were configured to be used on typical spacecraft compatible with both the Ariane and Space Shuttle launchers. Author (ESA)

**N79 31084\*** Committee on Science and Technology (U S House)

### NASA AUTHORIZATION, 1980, VOLUME 1, PART 3

Washington GPO 1979 610 p refs. Hearings on H R 1786 before the Subcomm. on Space Sci. and Applications of the Comm. on Sci. and Technol., 96th Congr., 1st Sess., 9-14 Feb 1979 (GPO 46-422) Avail. Subcomm. on Space Sci. and Applications

Testimony received from personnel at the Kennedy, Johnson, and Marshall Centers as well as at the National Space Technology Laboratories and the Michoud facility is presented. The President's budget plan for the Office of Space Science is discussed with implications for life sciences, planetary explorations, and physics and astronomy programs. Cooperative ventures with the European Space Agency are reviewed. A R H

**N79 31085\*** Committee on Science and Technology (U S House)

### NASA AUTHORIZATION, 1980, VOLUME 1, PART 4

Washington GPO 1979 760 p refs. Hearings on H R 1786 before the Subcomm. on Space Sci. and Applications of the Comm. on Sci. and Technol., 96th Congr., 1st Sess., 15, 21-22, 28 Feb., 9, 12 Mar 1979 (GPO 46-423) Avail. Subcomm. on Space Sci. and Applications

Budget requests for NASA's Office of Space Transportation are justified with emphasis on the supplemental request for space shuttle appropriations. Space applications programs related to using space as a relay point, for Earth observation, and to exploit its specific characteristics are discussed as well as the satellite conversion and transmission of energy to Earth. Field hearings at Rockwell International and Lockheed are included. A.R.H.

**N79-31270#** Erno Raumfahrttechnik G.m.b.H., Bremen (West Germany)

**ORBITAL TEST SATELLITE (OTS) THERMAL DESIGN AND IN-ORBIT PERFORMANCE**

D. Stumpel. In: ESA. Spacecraft Thermal and Environ. Control Systems. Oct. 1978. p. 27-34. refs.

Avail. NTIS. HC A99/MF A01

The major constraints put on the OTS thermal subsystem are reviewed and the essential steps of the development and test phases along with the final thermal layout summarized. Some emphasis is put on critical problems, their resolution and the consequences for follow-on projects. The subsystem in-orbit performance is briefly demonstrated and discussed vis a vis relevant American achievements. Author (ESA)

**N79-31271#** European Space Research and Technology Center, Noordwijk (Netherlands)

**ORBITAL ASSESSMENT OF OTS THERMAL PERFORMANCE**

J.-P. Bouchez, D. H. Howle, and D. Stumpel (Erno Raumfahrt-technik). In: ESA. Spacecraft Thermal and Environ. Control Systems. Oct. 1978. p. 35-45. refs.

Avail. NTIS. HC A99/MF A01

Thermally, the Orbital Test Program tasks are to evaluate the performance of the thermal control subsystem at regular intervals during satellite lifetime, to assess any degradation with time of the thermal coatings employed, and to assess the accuracy and adequacy of the mathematical thermal model. Subsidiary goals include assessment of the thermal distortion on the large dish antenna performance. The performance of the thermal sub-system to date is briefly assessed, and in-orbit temperatures obtained at the first solstice and first equinox conditions are compared with the corresponding predictions. The differences between flight and predicted temperatures are demonstrated graphically using histograms. Author (ESA)

**N79-31306#** Erno Raumfahrttechnik G.m.b.H., Bremen (West Germany)

**THE OTS HYDRAZINE REACTION CONTROL SYSTEM THERMAL CONDITIONING TECHNIQUE**

D. Stumpel. In: ESA. Spacecraft Thermal and Environ. Control Systems. Oct. 1978. p. 375-382. refs.

Avail. NTIS. HC A99/MF A01

Late development of OTS reaction control subsystems (RCS) thermal control is described. The final concept uses eight telecommand switches, provides separate heater operation for the redundant RCS branches, needs heater power only during sunlight periods of the mission, and maintains the temperatures of all components safely above the freezing point during all mission phases, including the critical transfer orbit and eclipse periods, without reaching unacceptable high temperatures under warm conditions. Experimental flight data show that the system performs within specifications. Author (ESA)

# SUBJECT INDEX

## Typical Subject Index Listing



This title is used to provide a description of the subject matter. When the title is insufficiently descriptive of the document content, a title extension is added, indicated from the title by three hyphens. The LTR or odd accession number is included in each entry to assist the user in locating the abstract in the abstract section of this issue. If appropriate, a report number is also included as an aid in identifying the document. The page and accession numbers are located beneath and to the right of the title. Under any one subject heading the accession numbers are arranged in sequence with the odd accession numbers appearing first.

## A

### ACCUMULATORS

WT SOLAR COLLECTORS

WT SOLAR REFLECTORS

### ACTION MEMBERS

WT MICROWAVE PASSPORTERS

### ACTUATORS

The dynamics and control of large flexible space structures, 2. Part 8: Shape and orientation control using point actuators  
[NASA-CR-150604] p0016 879-25122

### ADAPTIVE CONTROL

The dual-momentum control device for large space systems  
[AIAA 79-0923] p0013 879-34766

The dual-momentum control device for large space system - An example of distributed system adaptive control  
p0016 879-41106

On adaptive modal control of large flexible spacecraft  
[AIAA 79-1779] p0016 879-45606

A learning control system extension to the modal control of large flexible rotating spacecraft  
[AIAA 79-1781] p0016 879-45606

Indirect adaptive stabilization of a large, flexible, spinning spinning simulation studies  
p0017 879-50033

### ADAPTIVE CONTROL SYSTEMS

U ADAPTIVE CONTROL

### ADAPTIVE OPTICS

Electrostatically formed antennas ---  
Electrostatically Controlled Membrane Mirror for space applications  
[AIAA 79-0922] p0013 879-34763

### ADHESIVE BONDING

Graphite/Polyimide Composites --- conference on Composites for Advanced Space Transportation Systems  
[NASA-CR-2079] p0025 879-30297

### ADHESIVES

Graphite/Polyimide Composites --- conference on Composites for Advanced Space Transportation Systems  
[NASA-CR-2079] p0025 879-30297

### ADHESIVITIES

Active control of certain flexible systems using distributed and boundary control --- for large space structures  
[AIAA 79-1778] p0016 879-45606

### ATMOSPHERIC ORBIT TO ORBIT SHUTTLE

In a versatile orbit transfer stage feasible ---

Orbit Transfer Vehicle concepts, potential missions and evolution  
[AIAA 79-0846] p0029 879-34772

### ASTRONAUTICAL ENGINEERING

The 13th Aerospace Mechanisms Symposium  
[NASA-CR-2081] p0049 879-22539  
NASA authorization, 1980, volume 1, part 3  
[GPO-46-422] p0050 879-31094

### ASTROSPACE ENGINEERING

WT ASTROSPACE ENGINEERING  
Energy and aerospace; Proceedings of the Anglo-American Conference, London, England, December 5-7, 1978  
p0035 879-31908

Global services system - Space communication  
[AIAA 79-0946] p0010 879-34761

Satellite applications of metal-matrix composites  
p0024 879-43321  
NASA authorization, 1980, volume 1, part 3  
[GPO-46-422] p0050 879-31094

NASA authorization, 1980, volume 1, part 4  
[GPO-46-423] p0050 879-31095

### ASTROSPACE ENVIRONMENTS

Large space system - Charged particle environment interaction technology --- effects on high voltage solar array performance  
[AIAA 79-0913] p0046 879-34775

Space radiation effects on composite matrix materials - Analytical approaches  
p0023 879-43305

Effects of plasma sheath on solar power satellite array  
[AIAA PAPER 79-1507] p0037 879-46699

Materials degradation in space environments  
[AIAA PAPER 79-1508] p0025 879-46700

Large space system: Charged particle environment interaction technology  
[NASA-TN-79156] p0049 879-22186

Spacecraft Charging Technology, 1978  
[NASA-CR-2071] p0050 879-34081

Space environmental effects and the solar power satellite  
p0043 879-24026

Environmental factors of power satellites  
[SAMO-79-79-64] p0043 879-24021

### ASTROSPACE INDUSTRY

Satellite applications of metal-matrix composites  
p0024 879-43321

### ASTROSPACE SYSTEMS

Technical challenges of large space systems in the 21st century  
[AAS 79-155] p0001 879-24066

Graphite fiber reinforced glass matrix composites for aerospace applications  
p0023 879-43324

### ASTROSPACE TECHNOLOGY TRANSFER

Space to benefit mankind - 1980 to 2000  
[IAP PAPER 79-206] p0049 879-51354

### ASTROSPACE VEHICLES

Design fabrication and test of graphite/polyimide composite joints and attachments for advanced aerospace vehicles  
[NASA-CR-159080] p0011 879-24066

### ASTROSTATS

### U AIRSHIPS

### ASTRO (MATERIALS)

Materials evaluation for use in long-duration space missions  
p0024 879-43307

Materials degradation in space environments  
[AIAA PAPER 79-1508] p0025 879-46700

### AIR SHOOTING ENGINEER

### WT TURBOFAN ENGINES

### AIR TRANSPORTATION

New energy conversion techniques in space,

- applicable to propulsion --- powering of aircraft with laser energy from SPS  
[AIAA PAPER 79-1338] p0037 879-40499
- AIRCRAFT EQUIPMENT**
- WT AIRFRAME/ STRUCTURE COMPUTERS
- AIRCRAFT/SPACE CASE COMPUTERS**
- Autonomous mechanical assembly of the space shuttle: An overview  
[NASA-CR-158896] p0028 879-20201
- AIRCRAFT CONFIGURATIONS**
- Application of Lagrange Optimization to the drag polar utilizing experimental data  
[AIAA PAPER 79-1033] p0634 879-09335
- AIRCRAFT CONTROL**
- Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers  
p0095 879-45354
- AIRCRAFT DESIGN**
- Solar thermal aerostat research station /STARS/  
[IAF PAPER 79-35] p0491 879-53261
- AIRCRAFT GUIDANCE**
- Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers  
p0095 879-45354
- AIRCRAFT INSTRUMENTS**
- WT ATTITUDE INDICATORS
- AIRFOILS**
- WT SWEEP FORWARD WINGS
- AIRSHIPS**
- Solar thermal aerostat research station /STARS/  
[IAF PAPER 79-35] p0491 879-53261
- ALGEBRA**
- WT STATE VECTORS
- ALLOCATIONS**
- NASA authorization for fiscal year 1980, part 1  
[GPO-48-885] p0050 879-30093
- ALUMINUM BOND COMPOSITES**
- Satellite applications of metal-matrix composites  
p0024 879-43321
- ALUMINUM GRAPHITE COMPOSITES**
- Satellite applications of metal-matrix composites  
p0024 879-43321
- The application of metal-matrix composites to spaceborne parabolic antennas  
p0024 879-43322
- Thermally stable, thin, flexible graphite-fiber/aluminum sheet  
p0024 879-43323
- ANIDES**
- WT POLYIMIDES
- ANODES**
- U ATOMAREPOWERING ORBIT TO CREDIT SHUTTLE
- ANPENGAGE**
- U ELECTRIC CURRENT
- ANALYSIS (MATHEMATICS)**
- WT ERROR ANALYSIS
- Geometric model and analysis of rod-like large space structures  
[NASA-CR-158509] p0008 879-23120
- ANGULAR MOMENTUM**
- The dual momentum control device for large space systems - An example of distributed system adaptive control  
p0094 879-41106
- ANTENNA ARRAYS**
- WT STEERABLE ANTENNAS
- Long interface docking for large space structure assembly  
[AIAA 79-0954] p0014 879-34745
- Multi-cell satellite for the communications of year 2000  
[IAF PAPER 79-301] p0003 879-51405
- ANTENNA DESIGN**
- Large solid deployable reflector --- for satellite radio telescopes  
[AIAA 79-0925] p0009 879-34746
- Hypocycle /Romp/Column/ deployable reflector concept development for 50 to 100 meter antenna  
[AIAA 79-0935] p0009 879-34753
- A nonlinear stress-strain law for metallic meshes --- for large space antennas  
[AIAA 79-0936] p0023 879-34754
- An approach toward the design of large diameter offset-fed antennas --- wrap-around space antennas  
[AIAA 79-0938] p0010 879-34756
- Large multibeam space antennas  
[AIAA 79-0942] p0010 879-34756
- Calculated scan characteristic of a large spherical reflector antenna  
p0037 879-37300
- NASA technology for large space antennas  
p0032 879-52474
- Lightweight deployable microwave satellite antennas - Need, concepts and related technology problems  
[IAF PAPER 79-211] p0030 879-51411
- ANTENNA FIELDS**
- U ANTENNA RADIATION PATTERNS
- ANTENNA RADIATION PATTERNS**
- Calculated scan characteristic of a large spherical reflector antenna  
p0037 879-37300
- ANTENNAS**
- WT MICROWAVE ANTENNAS
- WT PARABOLIC ANTENNAS
- WT RADIO ANTENNAS
- WT RECTENNAS
- WT SATELLITE ANTENNAS
- WT SPACECRAFT ANTENNAS
- WT STEERABLE ANTENNAS
- Satellite Power System (SPS) Mapping of radiation areas for rectenna sites  
[NASA-CR-157435] p0042 879-23499
- APPROPRIATIONS**
- NASA authorization for fiscal year 1980, part 2  
[GPO-48-195] p0050 879-25427
- NASA authorization, 1980, volume 1, part 3  
[GPO-48-422] p0050 879-37084
- ARIP (IMPACT PREDICTION)**
- U COMPUTERIZED SIMULATION
- ARMED FORCES**
- WT ARMED FORCES (UNITED STATES)
- ARMED FORCES (UNITED STATES)**
- Satellite Power System (SPS) military implications  
[NASA-CR-157436] p0042 879-23500
- ARRAYS**
- WT ANTENNA ARRAYS
- WT SOLAR ARRAYS
- WT STEERABLE ANTENNAS
- ARTIFICIAL SATELLITES**
- WT COMMUNICATIONS SATELLITES
- WT COMMUNICATIONS TECHNOLOGY SATELLITE
- WT EDA SATELLITES
- WT EUROPEAN COMMUNICATIONS SATELLITE
- WT ORBITAL SPACE STATIONS
- WT ORBITAL WORKSHOPS
- WT OTS (TSM)
- WT SOLAR POWER SATELLITES
- WT SYNCHRONOUS SATELLITES
- Use of a large space structure as an orbital depot for hazardous wastes  
[IAF PAPER 79-209] p0019 879-51559
- ASSEMBLIES**
- Foldable beam  
[NASA-CR-15877-1] p0011 879-25425
- ASSEMBLING**
- WT ORBITAL ASSEMBLY
- ASSESSMENTS**
- WT TECHNOLOGY ASSESSMENT
- ASSIGNMENT**
- U ALLOCATIONS
- ASTRONOMICS**
- Trends in the design of future communications satellite systems  
[IAF PAPER 79-107] p0001 879-51609
- ASTRONAUTICS**
- Space to benefit mankind - 1980 to 2000  
[IAF PAPER 79-206] p0044 879-51556
- ASTRONOMICAL TELESCOPES**
- Stabilization of the shape of a deploying surface --- for large space radio telescope  
p0017 879-50681
- ASTRONOMY**
- WT RADIO ASTRONOMY
- WT SPACEBORNE ASTRONOMY
- ATMOSPHERIC MODELS**
- WT DYNAMIC MODELS
- ATTITUDE (INCLINATION)**
- The inclination change for solar sails and low earth orbit  
[AAS PAPER 79-104] p0030 879-47204
- ATTITUDE CONTROL**
- WT DIRECTIONAL CONTROL
- WT LONGITUDINAL CONTROL
- WT SATELLITE ATTITUDE CONTROL
- Attitude control requirements for future space systems  
[AIAA 79-0951] p0010 879-34757

Observability measures and performance sensitivity  
in the model reduction problem --- applied to  
flexible spacecraft attitude control  
[NASA-CP-87-2707]  
p0034 879-37207

The dual momentum control design for large space  
systems - An example of distributed system  
adaptive control  
[NASA-CP-87-41106]  
p0035 879-41106

Attitude control of agile flexible spacecraft  
[AIAA 79-1739]  
p0035 879-41301

A learning control system extension to the model  
control of large flexible rotating spacecraft  
[AIAA 79-1701]  
p0036 879-45400

Space construction base control system  
[NASA-CP-861288]  
p0037 879-24215

**ATTITUDE INDICATORS**  
Relative attitude of large space structures using  
radar measurements  
[AAS PAPERS 79-155]  
p0038 879-67230

**AUTOMATA THEORY**  
Autonomous mechanical assembly on the space  
shuttle: An overview  
[NASA-CP-750010]  
p0039 879-28201

**AUTONOMIC CONTROL**  
BT ADAPTIVE CONTROL  
BT DYNAMIC CONTROL  
BT FEEDBACK CONTROL  
BT NONLOCAL CONTROL  
BT OPTIMAL CONTROL  
BT PROPORTIONAL CONTROL

Stabilization of the shape of a deploying surface  
--- for large space radio telescope  
[NASA-CP-87-0403]  
p0039 879-50403

Pointing and control system enabling technology  
for future automated space missions  
[NASA-CP-87-0113]  
p0040 879-22177

**AUTOMATIC ROCKET IMPACT PREDICTORS**  
N COMPUTATIONAL SIMULATION

Large space system automated assembly technique  
[AIAA 79-0510]  
p0042 879-34757

**AUXILIARY POWER SOURCES**  
BT SPACE POWER FACTORS

## B

**BEAMS (RADIATION)**  
Large multibeam space antennas  
[AIAA 79-0942]  
p0040 879-34756

A power transmission concept for a European SPS  
system  
[NASA-CP-87-53407]  
p0040 879-53407

**BEAMS (SUPPORTS)**  
Development of a beam builder for automatic  
fabrication of large composite space structures  
[NASA-CP-87-12077-1]  
p0041 879-25425

Foldable beam  
[NASA-CP-87-12077-1]  
p0041 879-25425

Space fabrication demonstration system, technical  
volume  
[NASA-CP-861286]  
p0041 879-24213

Space fabrication demonstration system: Executive  
summary --- for large space structures  
[NASA-CP-861287]  
p0041 879-24214

**BEAMS (STRUCTURES)**  
N AIRSPEEDS

**BODIES OF REVOLUTION**  
BT SPHERES

Geometric model and analysis of rod-like large  
space structures  
[NASA-CP-87-150509]  
p0042 879-23120

**BONDING**  
BT ADHESIVE BONDING

**BURNS (EQUIPMENT)**  
Thermal control of a spacecraft-deployable lattice  
beam  
[AIAA PAPERS 79-1047]  
p0043 879-30631

**BOROSILICATE GLASS**  
Graphite fiber reinforced glass matrix composites  
for aerospace applications  
[NASA-CP-87-43234]  
p0043 879-43234

**BUILDING MATERIALS**  
N CONSTRUCTION MATERIALS

## C

**CARBON DIOXIDE LASERS**  
Anomalous intensity ratios of the resonance to  
intercombination lines of He-like ions in He-

and CO<sub>2</sub>-laser-produced plasma  
[NASA-CP-87-24021]  
p0047 879-24021

Potential of laser for SPS power transmission  
[NASA-CP-87-24021]  
p0047 879-24021

**CARBON FIBER REINFORCED PLASTICS**  
Graphite/Polyimide Composites --- conference on  
Composites for Advanced Space Transportation  
Systems  
[NASA-CP-87-2079]  
p0047 879-30297

Fabrication of structural elements --- using  
graphite/PMMA-PS  
[NASA-CP-87-30304]  
p0047 879-30304

Graphite/polyimide state-of-the-art panel  
discussion  
[NASA-CP-87-30320]  
p0047 879-30320

**CARBON FIBERS**  
Graphite fiber reinforced glass matrix composites  
for aerospace applications  
[NASA-CP-87-43234]  
p0043 879-43234

**CARTRIDGE ACTUATED DEVICES**  
N ACTUATORS

**CFRP**  
N CARBON FIBER REINFORCED PLASTICS

**CHARGE CARRIERS**  
BT PSEUDO ELECTRICITY

**CHARGE DISTRIBUTION**  
Plasma sheath effects and voltage distributions of  
large high-power satellite solar arrays  
[NASA-CP-87-24024]  
p0043 879-24024

Effects of electron irradiation on large  
insulating surfaces used for European  
Communications Satellites  
[NASA-CP-87-24034]  
p0043 879-24034

**CHARGED PARTICLES**  
BT PSEUDO ELECTRICITY  
BT HELIUM PLASMA  
BT LASER PLASMAS  
BT PLASMA SHEATHS  
BT THERMAL PLASMAS

Large space system - Charged particle environment  
interaction technology --- effects on high  
voltage solar array performance  
[AIAA 79-0511]  
p0048 879-34775

Large space system: Charged particle environment  
interaction technology  
[NASA-TN-79156]  
p0049 879-22100

Magnetic shielding of large high-power satellite  
solar arrays using internal currents  
[NASA-CP-87-24026]  
p0043 879-24026

**CHEMICAL PLANTS**  
BT SILICON

**CHEMICAL PROPULSION**  
Space propulsion technology overview  
[AIAA 79-0860]  
p0049 879-34704

Low-thrust chemical orbit transfer propulsion  
[AIAA PAPERS 79-1102]  
p0050 879-30015

Low-thrust chemical orbit transfer propulsion  
[NASA-TN-79190]  
p0050 879-25129

**CHEMICAL REACTION CONTROL**  
The OCS hydrazine reaction control system thermal  
conditioning technique  
[NASA-CP-87-31304]  
p0051 879-31304

**CHEMICAL REACTIONS**  
New highly conducting coordination compounds  
[AD-8064735]  
p0050 879-22261

**CHEMOCATALYTIC REACTIONS**  
N CHEMICAL PROPULSION

**CIRCULAR ORBITS**  
Assessment of the errors of an analytical method  
of calculating the geocentric trajectories of a  
solar sail  
[NASA-CP-87-53003]  
p0050 879-53003

**CIRCULAR TUBES**  
Dimensional stability investigation -  
Graphite/epoxy truss structure  
[NASA-CP-87-43130]  
p0049 879-43130

**CLOSED LOOP SYSTEMS**  
N FEEDBACK CONTROL

**COATINGS**  
BT THERMAL CONTROL COATINGS

**COLUMNS (SUPPORTS)**  
Optimization of triangular loaded truss columns  
with tubular compression members for space  
application  
[NASA-CP-87-44062]  
p0050 879-44062

**COMMUNICATION NETWORKS**  
Communication architecture for large geostationary  
platforms  
[ISF PAPERS 79-300]  
p0051 879-39404



The critical technical issues of future  
 pervasive broadband low-cost communication  
 networks  
 [IAF PAPER 79-342] p0003 879-53406

**COMMUNICATION SATELLITES**  
**NT COMMUNICATIONS TECHNOLOGY SATELLITE**  
**NT EUROPEAN COMMUNICATIONS SATELLITE**  
 Stability analysis of a flexible spacecraft with a  
 sampled-data attitude sensor  
 p0007 879-54516

Satellite clusters  
 p0002 879-51109

Large geostationary communications platform  
 [IAF PAPER 79-290] p0010 879-51360

Multi-cell satellite for the communications of  
 year 2000  
 [IAF PAPER 79-301] p0001 879-53405

Trends in the design of future communications  
 satellite systems  
 [IAF PAPER 79-307] p0003 879-53409

Employment of large structure communications  
 satellites for emergency calls  
 [IAF PAPER 79-316] p0003 879-51413

Space telecommunications at present and in future  
 [IAF PAPER 79-1155-06] p0049 879-53054

Feasibility study for a satellite frequency  
 modulated radio communication system  
 [ESA-CP-1151-DEL-1] p0004 879-27376

**COMMUNICATION SYSTEMS**  
**NT TELECOMMUNICATION**  
**COMMUNICATIONS TECHNOLOGY SATELLITE**  
 Canadian development of large deployable solar  
 arrays for communications spacecraft  
 p0050 879-50754

**COMPLEX SYSTEMS**  
 New highly connecting coordination compounds  
 [AD-A064735] p0040 879-22261

**COMPOSITE MATERIALS**  
**NT ALUMINUM-BASED COMPOSITES**  
**NT ALUMINUM GRAPHITE COMPOSITES**  
**NT CARBON FIBER REINFORCED PLASTICS**  
**NT GRAPHITE-EPoxy COMPOSITE MATERIALS**  
**NT LAMINATES**  
**NT METAL MATRIX COMPOSITES**  
**NT POLYMER MATRIX COMPOSITE MATERIALS**  
 Graphite fiber reinforced glass matrix composites  
 for aerospace applications  
 p0023 879-43334

Space radiation effects on composite matrix  
 materials - Analytical approaches  
 p0023 879-43305

Space radiation effects on spacecraft materials  
 p0020 879-43306

Solar power satellite - Putting it together ---  
 fabrication, composite materials, and building  
 site considerations  
 p0037 879-49399

Development of a beam builder for automatic  
 fabrication of large composite space structures  
 p0011 879-22561

Satellite Power System (SPS) resource requirements:  
 structural materials, energy and land  
 [NASA-CR-150880] p0002 879-13492

Graphite/polyimide state-of-the-art panel  
 discussion  
 p0024 879-40320

New flexible substrates with anti-charging layers  
 for advanced lightweight solar arrays  
 p0025 879-50717

**COMPOSITE STRUCTURES**  
**NT LAMINATES**  
 Space radiation effects on composite matrix  
 materials - Analytical approaches  
 p0023 879-43305

Derivation of the equations of motion for complex  
 structures by symbolic manipulation  
 p0007 879-52741

**COMPOSITES**  
**NT COMPOSITE MATERIALS**  
**COMPOSITION (PROPERTY)**  
**NT POLYMER COMPOSITES**  
**COMPUTATION**  
**NT COST CALCULATION**  
**COMPUTER GRAPHICS**  
 Geometric model and analysis of rod-like large  
 space structures  
 [NASA-CR-150509] p0008 879-21128

**COMPOSITE METHODS**  
**NT COMPOSITE PROCESSES**

**COMPUTER PROGRAMS**

Large Advanced Space System (LASS) Computer Program  
 [NASA 79-0504] p0007 879-54712

Derivation of the equations of motion for complex  
 structures by symbolic manipulation  
 p0007 879-52741

**COMPUTER SIMULATION****NT COMPUTERIZED SIMULATION****COMPUTERIZED CONTROL****NT MATHEMATICAL CONTROL****COMPUTERIZED DESIGN**

Design and operations technologies - Integrating  
 the pieces --- for future space systems design  
 [NASA 79-0505] p0001 879-54702

Large Advanced Space System (LASS) Computer Program  
 [NASA 79-0504] p0007 879-54712

**COMPUTERIZED SIMULATION**

Indirect adaptive stabilization of a large,  
 flexible, spinning spacecraft simulation system  
 p0017 879-50013

Computer modeling for a space power transmission  
 system  
 p0010 879-51901

**COMPUTERS****NT AIRBORNE/SPACEBORNE COMPUTERS****CONCENTRATION (COMPOSITION)****NT MOISTURE CONTENT****CONCENTRATORS**

Satellite solar power station designs with  
 concentrators and radiating control  
 [IAF PAPER 79-196] p0019 879-51116

**CONFERENCES**

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 Anglo-American Conference, London, England,  
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 p0015 879-31908

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 p0047 879-36701

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 p0023 879-43120

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 [NASA-CR-2081] p0049 879-22519

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 [NASA-CR-2071] p0050 879-26001

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 Composites for Advanced Space Transportation  
 Systems  
 [NASA-CR-2079] p0025 879-40297

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 ESTEC, Netherlands, Sep. 1978  
 [CP-180] p0046 879-30730

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 [GPO-43-435] p0050 879-25527

Solar power satellite  
 [GPO-45-997] p0043 879-24212

NASA authorization for fiscal year 1980, part 1  
 [GPO-44-885] p0050 879-30091

Solar Power Satellite Research, Development, and  
 Demonstration Program Act of 1978  
 [GPO-35-994] p0046 879-30724

NASA authorization, 1980, volume 1, part 1  
 [GPO-46-422] p0050 879-31004

NASA authorization, 1980, volume 1, part 4  
 [GPO-46-423] p0050 879-31005

**CONNECTIONS****NT JOINTS (JUNCTIONS)**

## CONSTRUCTION

Satellite Power System (SPS) concept definition study, exhibit C, Volume 1: Executive summary [NASA-CR-161216] p0041 879-23606

Space construction system analysis study, Task 3: Construction system shuttle integration [NASA-CR-166296] p0050 879-30267

Space construction data base [NASA-CR-160297] p0004 879-30268

## CONSTRUCTION MATERIALS

Space fabrication demonstration system: Executive summary --- for large space structures [NASA-CR-161287] p0011 879-29216

## CONSTRUCTION

## WT SOLAR CONSTRUCTION

## CONTINUOUS WAVE LASERS

Solar-pumped lasers for space power transmission [AIAA PAPER 79-1015] p0017 879-36202

## CONTROL COMPENSATED VEHICLES

Observability measures and performance sensitivity in the model reduction problem --- applied to flexible spacecraft attitude control p0014 879-37287

Application of Lagrange optimization to the drag polar utilizing experimental data [AIAA PAPER 79-1833] p0614 879-09335

## CONTROL DEVICES

## U CONTROL EQUIPMENT

## CONTROL EQUIPMENT

## WT TELEOPERATORS

The dynamics and control of large flexible space structures, 2, Part 8: Shape and orientation control using joint actuators [NASA-CR-156686] p0010 879-25922

## CONTROL SIMULATION

Control of large flexible space structures using pole placement design techniques [AIAA 79-1738] p0015 879-05380

Attitude control of agile flexible spacecraft [AIAA 79-1739] p0015 879-05381

Optimal local control of flexible structures --- for space structures [AIAA 79-1740] p0015 879-05382

## CONTROL STABILITY

Control of large space structures using equilibrium enforcing optimal control [AIAA 79-0927] p0011 879-36767

Stability of distributed control for large flexible structures using positivity concepts [AIAA 79-1780] p0014 879-05607

Stability of proportional-plus-derivative-plus-integral control of flexible spacecraft p0010 879-53905

## CONTROL THEORY

Stability bounds for the control of large space structures p0010 879-05699

Flexible spacecraft control by model error sensitivity suppression p0017 879-09633

## CONTROLLERS

On cost-sensitivity controller design methods for uncertain dynamic systems p0017 879-09635

## COORDINATES

## WT GEOCENTRIC COORDINATES

## COST ANALYSIS

Cost comparisons for the use of nonterrestrial materials in space manufacturing of large structures [AIAA PAPER 79-115] p0030 879-53302

Satellite Power System (SPS) concept definition study, exhibit C, Volume 2, part 2: System engineering, cost and programming [NASA-CR-161220] p0002 879-23606

Satellite Power System (SPS) financial management scenario [NASA-CR-157430] p0041 879-23502

## COST EFFICIENCIES

Space propulsion technology overview [AIAA 79-0960] p0020 879-30704

On cost-sensitivity controller design methods for uncertain dynamic systems p0017 879-09635

## COST ESTIMATES

Satellite Power System (SPS) concept definition study, exhibit C, Volume 2, part 2: System engineering, cost and programming, appendices

[NASA-CR-161221] p0042 879-23607

## COST REDUCTION

A space-based orbital transfer vehicle - Bridge to the future [AIAA 79-0865] p0047 879-34705

## COUPLING

Dynamic qualification of large space structures by means of modal coupling techniques [IAP PAPER 79-107] p0008 879-51299

## CRITERIA

## WT STRUCTURAL DESIGN CRITERIA

## CYBERNETICS

Autonomous mechanical assembly on the space shuttle: An overview [NASA-CR-158010] p0020 879-20201

## CYCLES

## WT SAWING CYCLE

## D

## DAMAGE

## WT RADIATION DAMAGE

## DAMPING

## WT VIBRATION DAMPING

## DAMPNESS

## U HUMIDITY CONTROL

## DATA BASES

Space construction data base [NASA-CR-160297] p0004 879-30268

## DATA PROCESSING

## WT SIGNAL PROCESSING

## DATA PROCESSING EQUIPMENT

## WT ALPHANUMERIC/SPACEBORNE COMPUTERS

## WT MICROPROCESSORS

## DATA SAMPLING

Stability analysis of a flexible spacecraft with a sampled-data attitude sensor p0007 879-36516

## DECOUPLING

Decoupling control of a long flexible beam in orbit --- state variable feedback control for large space system [AAS PAPER 79-150] p0016 879-07236

## DELIVERY

## WT PAYLOAD DELIVERY (STS)

## DENSITY (NUMBER/VOLUME)

## WT PLASMA DENSITY

## DEPLOYMENT

Large solid deployable reflector --- for satellite radio telescopes [AIAA 79-0925] p0009 879-34706

Deployable multi-payload platform [AIAA 79-0926] p0009 879-34706

Teleoperator system for management of satellite deployment and retrieval p0027 879-60539

## DESIGN ANALYSIS

Thermal control design analysis of an on-orbit assembly spacecraft [AIAA 79-0917] p0007 879-34740

Study of high stability structural systems:

Pre-phase A

[DT-RSS-5] p0012 879-30500

Canadian development of large deployable solar arrays for communications spacecraft p0050 879-30754

## DESIGN OF EXPERIMENTS

## U EXPERIMENTAL DESIGN

## DIMENSIONAL STABILITY

Dimensional stability investigation - Graphite/epoxy truss structure p0024 879-01330

## DIRECT POWER GENERATORS

## WT SOLAR CELLS

## DIRECTIONAL ANTENNAS

## WT PARABOLIC ANTENNAS

## WT STEERABLE ANTENNAS

## DIRECTIONAL CONTROL

The dual-momentus control device for large space systems [AIAA 79-0923] p0013 879-34706

## DISINTEGRATED

## U AIRCRAFTS

## DISINTEGRATED

## U PARABOLIC REFLECTORS

## DISPOSAL

## WT WASTE DISPOSAL

## DISTANCE MEASURING EQUIPMENT

## WT LASER RANGE FINDERS



## DISTRIBUTED PARAMETER SYSTEMS

p0008 879-22425

- The dual-momentum control device for large space systems  
[AIAA 79-0923] p0013 879-30704
- Nonreflective boundary control of a vibrating string --- application to electrostatically controlled large space antenna mirror antenna  
[AIAA 79-0950] p0013 879-30763
- On adaptive modal control of large flexible spacecraft  
[AIAA 79-1770] p0016 879-45006
- Distributed control of two typical flexible structures  
[IAP PAPER 79-292] p0019 879-51362

## DISTRIBUTION (PROPERTY)

NT ANTENNA RADIATION PATTERNS

NT CHARGE DISTRIBUTION

NT JUNCTION CONCENTRATION

## DOCKING

N SPACECRAFT DOCKING

## DOMESTIC SATELLITE COMMUNICATIONS SYSTEMS

- Communication architecture for large geostationary platform  
[IAP PAPER 79-100] p0011 879-51656

## DRAG REDUCTION

- Application of Lagrange Optimization to the drag polar utilizing experimental data  
[AIAA PAPER 79-1113] p0630 879-09335

## DURATION

N TIME

## DYNAMIC CHARACTERISTICS

NT CONTROL STABILITY

NT C- CROCAPT STABILITY

- Dynamic and control of large space structures - An overview  
p0017 879-49832

- Dynamic qualification of large space structures by means of modal coupling techniques  
[IAP PAPER 79-107] p0018 879-51299

## DYNAMIC CONTROL

- On cost-sensitivity controller design methods for uncertain dynamic systems  
p0017 879-49835

## DYNAMIC MODELS

- Observability measures and performance sensitivity in the model reduction problem --- applied to flexible spacecraft attitude control  
p0019 879-37207
- Modal truncation for flexible spacecraft  
[AIAA PAPER 79-1765] p0017 879-52555

## DYNAMIC PROPERTIES

N DYNAMIC CHARACTERISTICS

## DYNAMIC RESPONSE

- The dynamics and control of large flexible space structures, J. Part A: Shape and orientation control using joint actuators  
[NASA-CR-150684] p0019 879-25122

## DYNAMIC STABILITY

NT CONTROL STABILITY

NT SPACECRAFT STABILITY

## DYNAMIC STRUCTURAL ANALYSIS

- Modal truncation for flexible spacecraft  
[AIAA PAPER 79-1765] p0017 879-52555
- General dynamics of a large class of flexible satellite systems  
[IAP PAPER 79-192] p0019 879-51366

## E

## EARTH OBSERVATIONS (FROM SPACE)

- A Microwave Radiometer Spacecraft, some control requirements and concepts  
[AIAA 79-1777] p0002 879-45423
- Platform in space: Evolutionary trends  
p0005 879-30879

## EARTH ORBITAL REMOVED

- On-orbit assembly of large Space Structure (LSS) using an autonomous rendezvous and docking  
[AAS PAPER 79-100] p0027 879-47201

## EARTH ORBITS

- Preliminary design for a space based orbital transfer vehicle  
[AIAA 79-0897] p0018 879-30120
- Decoupling control of a long flexible beam in orbit --- state variable feedback control for large space system  
[AAS PAPER 79-150] p0016 879-47216
- Some activities and vehicle concepts envisioned for future earth orbital missions

## EARTH OBSERVANCES

- Mission specification for three generic mission classes  
[NASA-CR-150040] p0004 879-23526

## EARTH SATELLITES

- NT COMMUNICATION SATELLITES
- NT COMMUNICATIONS TECHNOLOGY SATELLITE
- NT EIA SATELLITES
- NT EUROPEAN COMMUNICATIONS SATELLITE
- NT CTS (ESA)
- NT SOLAR POWER SATELLITES
- NT SYNCHRONOUS SATELLITES

## ECONOMIC ANALYSIS

- An economic analysis of a commercial approach to the design and fabrication of a space power system  
[AIAA 79-0934] p0016 879-30737
- An economic analysis of a commercial approach to the design and fabrication of a space power system  
[NASA-TN-79753] p0040 879-22593
- Space-based solar power conversion and delivery system study. Volume 1: Executive summary  
[NASA-CR-150294] p0040 879-22617

## ECONOMIC FACTORS

- New energy conversion techniques in space, applicable to propulsion --- powering of aircraft with laser energy from SPS  
[AIAA PAPER 79-1130] p0017 879-40890

## ECOPOLITICS

- The origins of the eighteen Environment, economic, energy; Proceedings of the twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Books 1 & 2  
p0023 879-43228

## ECS

N EUROPEAN COMMUNICATIONS SATELLITE

## EFFECTIVENESS

NT COST EFFECTIVENESS

## EFFECTORS

N CONTROL EQUIPMENT

## EFFICIENCY

- NT ENERGY CONVERSION EFFICIENCY
- NT TRANSMISSION EFFICIENCY

## ELASTIC PROPERTIES

NT AEROELASTICITY

## ELASTOSTATICS

- Observability measures and performance sensitivity in the model reduction problem --- applied to flexible spacecraft attitude control  
p0019 879-37207

## ELECTRIC CURRENT

NT ELECTRIC DISCHARGES

NT LIGHTNING

- Plasma sheath effects and voltage distribution of large high-power satellite solar arrays  
p0011 879-24024

## ELECTRIC DISCHARGES

NT LIGHTNING

- Environmental interaction implications for large space systems  
p0008 879-24027
- Effects of electron irradiation on large insulating surfaces used for European Communications Satellites  
p0025 879-24036

## ELECTRIC GENERATORS

NT SOLAR CELLS

NT SOLAR GENERATORS

- SOLARPS - A new hope for solar energy  
p0007 879-33992
- Orbital antenna farm power system: challenges  
p0002 879-43092

## ELECTRIC POTENTIAL

- Plasma sheath effects and voltage distribution of large high-power satellite solar arrays  
p0011 879-24024

## ELECTRIC POWER CONVERSION

N ELECTRIC GENERATORS

## ELECTRIC POWER PLANTS

- Solar power satellites for Europe  
[IAP PAPER 79-177] p0019 879-51330
- System definition space based power conversion systems: Executive summary  
[NASA-CR-150297] p0040 879-22616

## ELECTRIC POWER SUPPLIES

- NT SPACECRAFT POWER SUPPLIES
- A programmable power processor for a 20-kW power module  
[NASA-TN-79215] p0021 879-26001

## ELECTRIC POWER TRANSMISSION

Computer modeling for a space power transmission system p0036 879-51961

The technology base for the microwave power transmission system in the SPS p0036 879-51963

System definition space based power conversion systems: Executive summary [NASA-CR-150209] p0040 879-22616

## ELECTRIC PROPULSION

## WT ION PROPULSION

## WT SOLAR ELECTRIC PROPULSION

Space propulsion technology overview [NASA 79-0860] p0029 879-36706

Payload capacity of Ariane launched geostationary satellites using an electric propulsion system for orbit raising [IAP PAPER 79-12] p0030 879-55250

Primary electric propulsion for future space missions [NASA-TM-79961] p0030 879-22190

Plasma particle trajectories around spacecraft propelled by ion thrusters p0039 879-26029

## ELECTRIC ROCKET ENGINES

## WT ION ENGINES

## WT PROCEEDING DESIGN ENGINES

## WT PLASMA ENGINES

## ELECTRICAL CONDUCTIVITY

## U ELECTRICAL RESISTIVITY

## ELECTRICAL PROPERTIES

## WT CHARGE DISTRIBUTION

## WT ELECTRICAL RESISTIVITY

## ELECTRICAL RESISTIVITY

New highly conducting coordination compounds [AD-A064735] p0040 879-22261

## ELECTRICITY

## WT STATIC ELECTRICITY

## ELECTROGENERATORS

## U ELECTRIC GENERATORS

## ELECTROMAGNETIC CONTROL

## U REMOTE CONTROL

## ELECTROMAGNETIC PROPAGATION

## U ELECTROMAGNETIC WAVE TRANSMISSION

## ELECTROMAGNETIC SHIELDING

## WT RADIO FREQUENCY SHIELDING

## ELECTROMAGNETIC WAVE TRANSMISSION

## WT IONOSPHERIC PROPAGATION

## WT MICROWAVE TRANSMISSION

New methods for the conversion of solar energy to A. F. and laser power [NASA PAPER 79-1436] p0036 879-36966

## ELECTROMECHANICAL EFFECTS

The 13th Aerospace Mechanics Symposium [NASA-CR-2081] p0049 879-22719

## ELECTRON IRRADIATION

Effects of electron irradiation on large insulating surfaces used for European communications satellites p0023 879-36790

Effects of electron irradiation on large insulating surfaces used for European Communications Satellites p0025 879-26036

## ELECTRON TUBES

## WT KLYSTRONS

## ELECTRONIC EQUIPMENT

## WT PHOTOVOLTAIC CELLS

## WT SEMICONDUCTOR DEVICES

## WT DISCRETE ELECTRONIC EQUIPMENT

## ELECTRONICS

## WT FREE ELECTRONS

## ELECTROSTATIC EFFECT

## U ELECTRIC CURRENT

## ELECTROSTATIC PROPULSION

## WT ION PROPULSION

## ELECTROSTATICS

Electrostatically formed antennas --- Electrostatically Controlled Membrane Mirror for space applications [NASA 79-0922] p0013 879-36763

## ELECTROTECHNICAL ENGINES

## WT PLASMA ENGINES

## ELECTROMAGNETIC PARTICLES

## WT FREE ELECTRONS

## ELLIPTICAL ORBITS

## WT TRANSFER ORBITS

## ENERGIES

Employment of large structure communications satellites for emergency calls [IAP PAPER 79-8-36] p0021 879-50613

## ENERGY ABSORPTION

Nonreflective boundary control of a vibrating string --- application to electrostatically controlled large space membrane mirror antennas [NASA 79-0950] p0013 879-36763

## ENERGY CONVERSION

## WT SATELLITE SOLAR ENERGY CONVERSION

## WT SOLAR ENERGY CONVERSION

Results from Symposium on Future Orbital power systems technology requirements [NASA-TM-79125] p0004 879-22994

## ENERGY CONVERSION EFFICIENCY

Energy analysis of the Solar Power Satellite p0007 879-04960

Solar thermal concentrator research station /STWIS/ [IAP PAPER 79-35] p0041 879-55261

The NASA Lewis Research Center program in space solar cell research and technology --- efficient silicon solar cell development program p0045 879-32641

Solar photovoltaic research and development program of the Air Force Aero Propulsion Laboratory --- silicon solar cell applicable to satellite power systems p0045 879-32642

The JPL space photovoltaic program --- energy efficient not silicon solar cells for space applications p0045 879-32643

## ENERGY POLICY

Future programs in space --- impact on energy technology problems [AAS 79-180] p0049 879-36965

Solar power satellites for Europe [IAP PAPER 79-173] p0039 879-55336

Satellite Power Systems (SPS) concept definition study exhibit C, Volume 1: Experimental verification definition [NASA-CR-161236] p0041 879-22632

Satellite Power Systems (SPS) concept definition study, exhibit C, Volume 2: Special emphasis studies [NASA-CR-161236] p0041 879-22633

Satellite Power Systems (SPS) concept definition study, exhibit C, Volume 3: In-depth element investigation [NASA-CR-161236] p0041 879-22634

Solar power satellite [GPO-45-997] p0041 879-24212

Solar Power Satellite Research, Development, and Demonstration Program Act of 1976 [GPO-75-994] p0044 879-30726

Photovoltaic generators in space --- conference, ESTEC, Netherlands, Sep. 1976 [SP-140] p0044 879-30730

A study on solar arrays for programmes leading from the extension of Spacelab towards space platforms p0004 879-30746

Solar power satellites: The Engineering Challenges p0044 879-30750

Interface problem on an SPS solar array blanket p0044 879-30751

MOORE: A potential European contribution in developing large solar generators suitable for growing power levels up to SPS-systems p0044 879-30752

## ENERGY REQUIREMENTS

Satellite Power System (SPS) resource requirements (critical materials, energy and land) [NASA-CR-150600] p0042 879-22692

## ENERGY STORAGE

Inductive energy storage for MPD thrusters [NASA 79-0983] p0029 879-36790

Orbital antenna farm power systems challenges p0002 879-51092

## ENERGY STORAGE SYSTEMS

## U ENERGY STORAGE

## ENERGY TECHNOLOGY

An evolutionary solar power satellite program [AAS PAPER 79-153] p0035 879-21265

Energy and space: Proceedings of the Anglo-American Conference, London, England, December 5-9, 1976 p0035 879-31906

- Solar Power Satellite systems Definition  
p0025 879-35920
- First steps to the Solar Power Satellite  
p0036 879-37273
- Synchronous orbit power technology needs  
[AIAA 79-0916]  
p0048 879-34770
- Future programs in space --- impact on energy  
technology problems  
[AAS 78-080]  
p0068 879-34865
- The development of solar power satellites  
p0036 879-35488
- International Conference on Future Energy  
Concepts, London, England, January 30-February  
1, 1979, Proceedings  
p0036 879-37047
- The origins of the eighties: Environment,  
economics, energy; Proceedings of the  
Twenty-fourth National Symposium and Exhibition,  
San Francisco, Calif., May 8-10, 1979, Books 1 & 2  
p0023 879-81228
- European technology applicable to Solar Power  
Satellite Systems /SPS/  
[IAP PAPER 79-176]  
p0039 879-53335
- Satellite Power Systems (SPS) concept Definition  
study, exhibit C, Volume B: Experimental  
verification Definition  
[NASA-CN-361276]  
p0041 879-22612
- Satellite Power Systems (SPS) concept Definition  
study, exhibit C, Volume 1: Special emphasis  
studies  
[NASA-CN-361275]  
p0041 879-22611
- Satellite Power Systems (SPS) concept Definition  
study, exhibit C, Volume 4: In-depth element  
investigation  
[NASA-CN-361276]  
p0041 879-22610
- ENGINE DESIGN**  
NT ROCKETS ENGINE DESIGN
- ENGINEERS**  
NT HYDRAULIC ENGINEERS  
NT ICE ENGINEERS  
NT MECHANICAL ENGINEERS  
NT PLASMA ENGINEERS  
NT THERMAL ENGINEERS  
NT UPPER STAGE ROCKET ENGINEERS
- ENVIRONMENTAL EFFECTS**  
The development of solar power satellites  
p0036 879-35488
- Mission specification for three generic mission  
classes  
[NASA-CN-359088]  
p0004 879-27176
- Preliminary environmental assessment for the  
Satellite Power System (SPS), Volume 2:  
Detailed assessment  
[NASA-TN-80355]  
p0043 879-24436
- Environmental factors of power satellites  
[NASA-TN-79-66]  
p0043 879-20711
- ENVIRONMENTAL PROTECTION**  
The origins of the eighties: Environment,  
economics, energy; Proceedings of the  
Twenty-fourth National Symposium and Exhibition,  
San Francisco, Calif., May 8-10, 1979, Books 1 & 2  
p0023 879-81228
- ENVIRONMENTAL SIMULATION**  
NT SPACE ENVIRONMENTAL SIMULATION  
A combined spacecraft charging and pulsed X-ray  
simulation facility  
p0058 879-26054
- ENVIRONMENTAL CONTROL**  
Concept Definition for an extended duration  
orbiter SCLDS  
[NASA-CN-361265]  
p0041 879-23866
- ENVIRONMENTAL EFFECTS**  
NT AEROSPACE ENVIRONMENTAL  
NT SPACECRAFT ENVIRONMENTAL
- EOS (EARTH OBSERVATION)**  
A EARTH ORBITAL OBSERVATIONS
- EQUATIONS OF MOTION**  
Derivation of the equations of motion for complex  
structures by symbolic manipulation  
p0007 879-57701
- EXPLORATION**  
A CONSTRUCTION
- ERROR ANALYSIS**  
Relative attitude of large space structures using  
radio measurements  
[AIAA PAPER 79-877]  
p0036 879-47204
- Flexible spacecraft control by model error  
sensitivity suppression  
p0019 879-46011
- Assessment of the errors of an analytical method  
of calculating the geocentric trajectories of a  
solar sail  
p0010 879-53063
- ESA SATELLITES**  
NT EUROPEAN COMMUNICATIONS SATELLITE  
NT CTS (CTS)  
Effects of electron irradiation on large  
insulating surfaces used for European  
Communications Satellites  
p0024 879-24036
- ESDO SATELLITES**  
A THE SATELLITES
- ESTIMATES**  
NT COST ESTIMATES
- EUROPEAN COMMUNICATIONS SATELLITE**  
Effects of electron irradiation on large  
insulating surfaces used for European  
Communications Satellites  
p0023 879-36190
- EUROPEAN SPACE PROGRAMS**  
A review of some critical aspects of satellite  
power systems  
p0035 879-35921
- European aspects of Solar Satellite Power systems  
p0035 879-35923
- Solar power satellites for Europe  
[IAP PAPER 79-173]  
p0039 879-53336
- European technology applicable to Solar Power  
Satellite Systems /SPS/  
[IAP PAPER 79-176]  
p0039 879-53335
- A power transmission concept for a European SPS  
system  
p0039 879-53607
- Photovoltaic generators in space --- conference,  
Rijswijk, Netherlands, Sep. 1978  
[CP-160]  
p0044 879-30730
- A study on solar arrays for programmes leading  
from the extension of Spacelab towards space  
platforms  
p0004 879-30708
- MOON: A potential European contribution in  
developing large solar generators suitable for  
proving power levels up to SPS-systems  
p0004 879-30702
- EUROPEAN SPACE OBSERVATION ORGANISATION SET**  
A THE SATELLITES
- EXHAUST GASES**  
Magnetospheric and ionospheric impact of  
large-scale space transportation with ion engines  
[AD-806487]  
p0011 879-23134
- EXHAUST JETS**  
A EXHAUST GASES
- EXPANDABLE STRUCTURES**  
Expandable modules for large space structures  
[AIAA 79-0926]  
p0009 879-34765
- EXPERIMENTAL DESIGN**  
The 13th Aerospace Mechanics Symposium  
[NASA-CN-2001]  
p0045 879-22539
- Development of a movable, thermally conducting  
joint for application to deployable radiators  
p0012 879-31374
- EXPLOSION**  
NT SPACE EXPLOSION
- EXTENSIONS**  
Concept Definition for an extended duration  
orbiter SCLDS  
[NASA-CN-361265]  
p0041 879-23866
- EXTRATERRESTRIAL INTELLIGENCE**  
The possibilities of SPTI from space  
p0012 879-30859
- EXTRATERRESTRIAL OBSERVATION**  
Energy for the year 2000 - The SPS concept  
p0010 879-53074
- Cost comparisons for the use of nonterrestrial  
materials in space manufacturing of large  
structures  
[IAP PAPER 79-177]  
p0039 879-53302
- EXTRATERRESTRIAL ACTIVITY**  
Construction in space - Toward a fresh definition  
of the man/machine relation  
p0012 879-30859
- Maned remote work station - Safety and rescue  
considerations  
[IAP PAPER 79-8-79]  
p0019 879-46011

## F

## FAB (PROGRAMMING LANGUAGE)

## F FORTRAN

## FABRICATION

## FAB SPACE MANUFACTURING

An economic analysis of a commercial approach to the design and fabrication of a space power system [AIAA 79-0914] p0036 A79-34717

## FATIGUE LIFE

The dimensioning of complex steel members in the range of endurance strength and fatigue life p0047 A79-24000

## FEASIBILITY ANALYSIS

In a versatile orbit transfer stage feasible --- Orbit Transfer Vehicle concepts, potential missions and evolutions [AIAA 79-0866] p0029 A79-34772

Satellite solar power stations - Current status and prospects p0036 A79-37004

Feasibility study for a satellite frequency modulated radio communication system [ESA-CN(P)-1151-VCL-1] p0004 A79-27336

## FEDERAL BUDGETS

NASA authorization for fiscal year 1980, part 2 [GPO-43-135] p0050 A79-25927

NASA authorization for fiscal year 1980, part 3 [GPO-44-885] p0050 A79-30093

NASA authorization, 1980, volume 1, part 3 [GPO-46-422] p0050 A79-31084

NASA authorization, 1980, volume 1, part 4 [GPO-46-423] p0050 A79-31085

## FEEDBACK CONTROL

Direct velocity feedback control of large space structures p0019 A79-34523

Stability bounds for the control of large space structures p0014 A79-41699

Orthogonal subspace reduction of optimal regulator order --- for spacecraft structural vibrations [AIAA 79-1742] p0015 A79-45384

Decoupling control of a long flexible beam in orbit --- state variable feedback control for large space systems [AAS PAPER 79-156] p0016 A79-47236

Direct output feedback control of large space structures p0017 A79-49814

## FIBER COMPOSITES

## FIBER CARBON FIBER REINFORCED PLASTICS

## FIBER STRENGTH

Graphite fiber reinforced glass matrix composites for aerospace applications p0023 A79-43234

## FIBERS

## FIBER CARBON FIBERS

## FIBER-KING AIRCRAFT

## FIBER AIRCRAFT CONFIGURATIONS

## FLAME INTERACTION

## FLAME CHEMICAL REACTIONS

## FLAP CONTROL

## FLAP AIRCRAFT CONTROL

## FLEXIBLE BODIES

Control of large flexible space structures using pole placement design techniques [AIAA 79-1738] p0015 A79-45380

Attitude control of agile flexible spacecraft [AIAA 79-1739] p0015 A79-45381

Optimal local control of flexible structures --- for space structures [AIAA 79-1740] p0015 A79-45382

Active control of certain flexible systems using distributed and boundary control --- for large space structures [AIAA 79-1770] p0016 A79-45405

On adaptive modal control of large flexible spacecraft [AIAA 79-1779] p0016 A79-45406

Stability of distributed control for large flexible structures using positivity concepts [AIAA 79-1780] p0016 A79-45407

A learning control system extension to the modal control of large flexible rotating spacecraft [AIAA 79-1781] p0016 A79-45408

Large angle maneuver strategies for flexible spacecraft

[AAS PAPER 79-156] p0016 A79-47236  
Decoupling control of a long flexible beam in orbit --- state variable feedback control for large

space systems [AAS PAPER 79-158] p0016 A79-47236  
Flexible spacecraft control by model error sensitivity suppression

p0017 A79-49813  
Indirect adaptive stabilization of a large, flexible, spinning spacecraft simulation studies

p0017 A79-50033  
Modal truncation for flexible spacecraft [AIAA PAPER 79-1765] p0007 A79-52555

General dynamics of a large class of flexible satellite systems [IAF PAPER 79-192] p0008 A79-53386

Distributed control of two typical flexible structures [IAF PAPER 79-212] p0018 A79-53382

Stability of proportional-plus-derivative-plus-integral control of flexible spacecraft p0018 A79-53985

See flexible substrates with anti-charging layers for advanced lightweight solar arrays p0025 A79-30737

## FLIGHT COMPUTERS

## FLIGHT AIRBORNE/SPACEBORNE COMPUTERS

## FLIGHT CONTROL

## FLIGHT CONTROL SYSTEMS

Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers p0015 A79-45385

## FLIGHT INSTRUMENTS

## FLIGHT ATTITUDE INDICATORS

## FLIGHT TESTS

## FLIGHT SPACE TRANSPORTATION SYSTEM FLIGHTS

## FLUID DYNAMICS

## FLUID MAGNETOHYDRODYNAMICS

## FLUID MECHANICS

## FLUID MAGNETOHYDRODYNAMICS

## FLYING WING AIRCRAFT

## FLYING PLATFORMS

## FLYING PLATFORM STABILITY

## FLYING PLATFORMS

## FLYING PLATFORMS

A technology program for large area space systems [AIAA 79-0921] p0001 A79-34702

Deployable multi-payload platform [AIAA 79-0928] p0009 A79-34700

Tractable platforms for science and applications payloads circa 1985 [AIAA 79-0931] p0009 A79-34704

## FOLDING STRUCTURES

Lightweight deployable microwave satellite antennae - Need, concepts and related technology problems [IAF PAPER 79-211] p0018 A79-53381

Foldable beam [NASA-CASL-LAB-12077-1] p0011 A79-25425

## FORECASTING

## FORECASTING PERFORMANCE PREDICTION

## FORECASTING TECHNOLOGICAL FORECASTING

## FORTRAN

Derivation of the equations of motion for complex structures by symbolic manipulation p0007 A79-52701

## FREE ELECTRONS

New methods for the conversion of solar energy to E. F. and laser power [AIAA PAPER 79-1416] p0036 A79-34886

## FREQUENCIES

## FREQUENCY FREQUENCIES

## FUEL CONSUMPTION

A method of controlling orbits of geostationary satellites with minimum fuel consumption p0047 A79-30782

## G

## GAS LASERS

## GAS CARBON DIOXIDE LASERS

## GAS TURBINE ENGINES

## GAS TURBOFAN ENGINES

## GASES

## GAS CHARGED PARTICLES

## GAS EXHAUST GASES

## GAS LASER PLASMAS

## GEOCENTRIC COORDINATES

## SUBJECT INDEX

## GEOCENTRIC COORDINATES

Assessment of the errors of an analytical method of calculating the geocentric trajectories of a solar sail  
p0016 879-53063

## GEOMAGNETIC EFFECTS

## U MAGNETIC EFFECTS

## GEOMAGNETIC STORMS

## U MAGNETIC STORMS

## GEOMETRICAL HYDROMAGNETICS

## U MAGNETOHYDRODYNAMICS

## GEOMETRY

Geometric model and analysis of rod-like large space structures  
[NASA-CR-158504]  
p0008 879-23128

## GEOSTATIONARY SATELLITES

## U SYNCHRONOUS SATELLITES

## GEOSYNCHRONOUS ORBITS

A method of controlling orbits of geostationary satellites with minimal fuel consumption  
p0047 879-30782

Orbit transfer vehicle propulsion for transfer of Shuttle-deployed large spacecraft to geosynchronous orbit  
[AIAA 79-0890]  
p0029 879-34716

Preliminary design for a space based orbital transfer vehicle  
[AIAA 79-0897]  
p0048 879-34728

Synchronous orbit power technology needs  
[AIAA 79-0916]  
p0048 879-34739

Orbit transfer operations for the Space Shuttle era  
[IAF PAPER 79-20]  
p0049 879-53255

Large geostationary communications platforms  
[IAF PAPER 79-210]  
p0030 879-53360

Communication architecture for large geostationary platforms  
[IAF PAPER 79-300]  
p0011 879-53606

A power transmission concept for a European SPS system  
p0039 879-53607

Space-based solar power conversion and delivery systems study, Volume 2: Engineering analysis  
[NASA-CR-150295]  
p0040 879-22618

Space-based solar power conversion and delivery systems study, Volume 3: Microwave power transmission studies  
[NASA-CR-150296]  
p0040 879-22619

## GEORADAR AND RADARS

## U HEATING EQUIPMENT

## GLASS

## UT BOROSILICATE GLASS

## GRAPHITE-EPoxy COMPOSITE MATERIALS

Moisture effects on spacecraft structures  
p0023 879-43302

The application of metal-matrix composites to spaceborne parabolic antennas  
p0024 879-43322

Dimensional stability investigation - Graphite/epoxy truss structure  
p0028 879-43330

Design fabrication and test of graphite/polyimide composite joints and attachments for advanced aerospace vehicles  
[NASA-CR-150000]  
p0011 879-24066

## GROUND BASED CONTROL

A space-based orbital transfer vehicle - bridge to the future  
[AIAA 79-0865]  
p0047 879-34705

## GROUND STATIONS

Solar power satellite ground stations  
p0037 879-44269

## GROUND TESTS

Space fabrication demonstration system, technical volume  
[NASA-CR-161266]  
p0011 879-29213

## GUIDANCE (NOTION)

## UT AIRCRAFT GUIDANCE

## UT SPACECRAFT GUIDANCE

## H

## HALL CURRENTS

## U ELECTRIC CURRENT

## HEAT EFFECTS

## U TEMPERATURE EFFECTS

## HEAT PIPES

LDEF transverse flat plate heat pipe experiment /S1005/ --- Long Duration Exposure Facility  
[AIAA PAPER 79-1077]  
p0023 879-38053

Externally pumped Rankine cycle thermal transport devices  
[AIAA PAPER 79-1091]  
p0048 879-38060

## HEAT RADIATIONS

## UT SPACECRAFT RADIATIONS

## HEAT REGULATION

## U TEMPERATURE CONTROL

## HEAT TRANSFER

Externally pumped Rankine cycle thermal transport devices  
[AIAA PAPER 79-1091]  
p0048 879-38060

## HEAT TRANSMISSION

## UT HEAT TRANSFER

## HEATING EQUIPMENT

Orbital Test Satellite (OTS) thermal design and in-orbit performance  
p0051 879-31270

## HEAVY LIFT LAUNCH VEHICLES

Satellite power system: Concept development and evaluation program, reference system report  
[DOD/IS-0021]  
p0039 879-23538

## HELICOPTER ATTITUDE INDICATORS

## U ATTITUDE INDICATORS

## HELIUM PLASMA

Isomalous intensity ratios of the resonance to intercombination lines of He-like ions in 9d- and 10d-laser-produced plasma  
p0047 879-24021

## HERMES SATELLITE

## U COMMUNICATIONS TECHNOLOGY SATELLITE

## HYPERODERING

## UT OPTICAL HYPERODERING

## HIGH VOLTAGES

Large space system - Charged particle environment interaction technology --- effects on high voltage solar array performance  
[AIAA 79-0913]  
p0048 879-34775

## HINGED MOTOR BLADES

## U HINGES

## HINGES

Foldable beam  
[NASA CR-158-12077-1]  
p0011 879-25425

## HLLV

## U HEAVY LIFT LAUNCH VEHICLES

## HORMANN TRAJECTORIES

## U TRANSFER ORBITS

## HORMANN TRANSFER ORBITS

## U TRANSFER ORBITS

## HYDRAULIC ACTUATORS

## U ACTUATORS

## HYDRAULIC ENGINES

The OTS hydrazine reaction control system thermal conditioning technique  
p0051 879-31306

## HYDRODYNAMICS

## UT MAGNETOHYDRODYNAMICS

## HYDROMAGNETICS

## U MAGNETOHYDRODYNAMICS

## HYDROMAGNETISM

## U MAGNETOHYDRODYNAMICS

## HYDROMECHANICS

## UT MAGNETOHYDRODYNAMICS

## HYDRAULIC PROPERTIES

## U MOISTURE CONTENT

## HYPERODERING

## UT OPTICAL HYPERODERING

## HYPERODERING

## UT OPTICAL HYPERODERING

## HYPERODERING

## UT OPTICAL HYPERODERING

## HYPERODERING

## UT OPTICAL HYPERODERING

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## UT OPTICAL HYPERODERING

## HYPERODERING

## UT OPTICAL HYPERODERING

## HYPERODERING

## UT OPTICAL HYPERODERING



## INTERFACIAL STABILITY

Long interface docking for large space structure assembly  
[AIAA 79-0954] p0014 A79-34765

## INTERFERENCE

WT VERY LONG INFLUENCE INTERFERENCE

## INTERLAYERS

WT MULTILAYER INSULATION

## INTERNAL COMBUSTION ENGINES

WT TURBOFAN ENGINES

## INTERPLANETARY PROPULSION

U INTERPLANETARY SPACECRAFT

## INTERPLANETARY SPACECRAFT

Planetary mission requirements, technology and design considerations for a solar electric propulsion stage  
[AIAA 79-0508] p0029 A79-34735

## ION ACCUMULATORS

Increased capabilities of the 30-cm diameter Mg ion thruster  
[AIAA 79-0930] p0030 A79-34774

## ION ENGINES

WT MERCURY ION ENGINES

Magnetospheric and ionospheric impact of large-scale space transportation with ion engines  
[AD-8065482] p0031 A79-23134

## ION PROPULSION

Plasma particle trajectories around spacecraft propelled by ion thrusters  
p0031 A79-24029

## IONIC PROPELLANTS

U ION ENGINES

## IONIZED GASES

WT CHARGED PARTICLES

WT LASER PLASMAS

WT PLASMA SHEATHS

WT THERMAL PLASMAS

## IONOSPHERIC ABSORPTION

U IONOSPHERIC PROPAGATION

## IONOSPHERIC PROPAGATION

Space-based solar power conversion and delivery systems study. Volume 1: Microwave power transmission studies  
[NASA-CR-150256] p0040 A79-22619

## IONOSPHERIC REFLECTION

U IONOSPHERIC PROPAGATION

## IP (IMPACT PREDICTION)

U COMPUTERIZED SIMULATION

## INASERS

U INFRARED LASERS

## IRRADIATION

WT ELECTRON IRRADIATION

## ISING MODEL

U MATHEMATICAL MODELS

J

## JET ENGINES

WT TURBOFAN ENGINES

## JITTER

U VIBRATION

## JOINTS (JUNCTIONS)

Dimensional stability investigation - Graphite/epoxy truss structure  
p0024 A79-41330

Design fabrication and test of graphite/polyimide composite joints and attachments for advanced aerospace vehicles  
[NASA-CR-150000] p0011 A79-24066

Development of a movable, thermally conducting joint for application to deployable radiators  
p0012 A79-31314

K

## KLYSTRONS

New methods for the conversion of solar energy to R. F. and laser power  
[AIAA PAPER 79-1496] p0034 A79-34846

L

## LAGRANGE MULTIPLIERS

Application of Lagrange Optimization to the drag polar utilizing experimental data  
[AIAA PAPER 79-1033] p0634 A79-49335

## LAMINATED MATERIALS

U LAMINATES

## LAMINATES

Moisture effects on spacecraft structures  
p0023 A79-41302

Thermally stable, thin, flexible graphite-fiber/aluminum sheet  
p0024 A79-41323

## LAMINATIONS

U LAMINATES

## LAND USE

Satellite Power System (SPS) resource requirements (critical materials, energy and land)  
[NASA-CR-150400] p0042 A79-23492

## LANGUAGES

WT FORTRAN

## LARGE SPACE STRUCTURES

A development strategy for the solar power satellite  
[AAS PAPER 78-154] p0035 A79-21266

Direct velocity feedback control of large space structures  
p0013 A79-34523

Orbit transfer vehicle propulsion for transfer of Shuttle-deployed large spacecraft to geosynchronous orbit  
[AIAA 79-0880] p0029 A79-34716

Large Advanced Space System /LASS/ Computer Program  
[AIAA 79-0904] p0007 A79-34732

Thermal control design analysis of an on-orbit assembly spacecraft  
[AIAA 79-0917] p0007 A79-34760

A technology program for large area space systems  
[AIAA 79-0921] p0001 A79-34762

The dual-momenta control device for large space systems  
[AIAA 79-0923] p0013 A79-34764

Expandable modules for large space structures  
[AIAA 79-0924] p0009 A79-34765

Control of large space structures using equilibrium enforcing optimal control  
[AIAA 79-0927] p0013 A79-34767

Deployable antenna technology development for the Large Space System Technology program  
[AIAA 79-0932] p0009 A79-34750

Haypole /Boop/Column/ deployable reflector concept development for 30 to 100 meter antenna  
[AIAA 79-0935] p0009 A79-34751

A nonlinear stress-strain law for metallic composites --- for large space antennas  
[AIAA 79-0936] p0023 A79-34754

Large space system automated assembly technique  
[AIAA 79-0939] p0027 A79-34757

Large multibeam space antennas  
[AIAA 79-0942] p0030 A79-34758

Long interface docking for large space structure assembly  
[AIAA 79-0954] p0014 A79-34765

Stability and control of future spacecraft systems  
[AIAA 79-0964] p0014 A79-34766

Attitude control requirements for future space systems  
[AIAA 79-0951] p0014 A79-34767

Large space system - Charged particle environment interaction technology --- effects on high voltage solar array performance  
[AIAA 79-0913] p0008 A79-34775

Technical challenges of large space systems in the 21st century  
[AAS 78-195] p0001 A79-34868

Space structure - A key to new opportunities --- deployable antenna and construction/servicing system  
[AAS PAPER 79-059] p0001 A79-36549

Low-thrust chemical orbit transfer propulsion  
[AIAA PAPER 79-1162] p0038 A79-39015

The dual momenta control device for large space systems - An example of distributed system adaptive control  
p0014 A79-41104

Control of large flexible space structures using pole placement design techniques  
[AIAA 79-1738] p0015 A79-45380

Orthogonal subspace reduction of optimal regulator order --- for spacecraft structural vibration  
[AIAA 79-1742] p0015 A79-45384

Active control of certain flexible systems using distributed and boundary control --- for large space structures  
[AIAA 79-1778] p0016 A79-45405

On adaptive modal control of large flexible spacecraft

- [AIAA 79-1779] p0016 A79-45406  
Stability of distributed control for large  
flexible structures using positivity concepts  
[AIAA 79-1780] p0016 A79-45407  
A learning control system extension to the modal  
control of large flexible rotating spacecraft  
[AIAA 79-1781] p0016 A79-45408  
A Microwave Radiometer Spacecraft, some control  
requirements and concepts  
[AIAA 79-1777] p0002 A79-45423  
Optimization of triangular laced truss columns  
with tubular compression members for space  
application p0010 A79-46362  
On-orbit assembly of Large Space Structures (LSS)/  
using an autonomous rendezvous and docking  
[AAS PAPER 79-100] p0027 A79-47201  
Relative attitude of large space structures using  
radar measurements  
[AAS PAPER 79-155] p0016 A79-47234  
Decoupling control of a long flexible beam in orbit  
--- state variable feedback control for large  
space system [AAS PAPER 79-158] p0016 A79-47236  
Dynamics and control of large space structures -  
An overview p0017 A79-49832  
Direct output feedback control of large space  
structures p0017 A79-49834  
Indirect adaptive stabilization of a large,  
flexible, spinning spacecraft Simulation studies  
p0017 A79-50033  
SEP solar array development testing p0030 A79-51904  
NASA technology for large space antennas  
p0002 A79-52674  
Construction of large space structures  
[IAF PAPER 79-106] p0010 A79-53298  
Dynamic qualification of large space structures by  
means of modal coupling techniques  
[IAF PAPER 79-107] p0008 A79-53299  
A technology base for near-term space platforms  
[IAF PAPER 79-110] p0002 A79-53300  
Superlight rotating reflectors in space  
[IAF PAPER 79-112] p0030 A79-53301  
Cost comparisons for the use of nonterrestrial  
materials in space manufacturing of large  
structures [IAF PAPER 79-115] p0030 A79-53302  
Orbital demonstration - The prelude to large  
operational structures in space  
[IAF PAPER 79-207] p0002 A79-53357  
New space initiatives through large generic  
structures [IAF PAPER 79-208] p0002 A79-53358  
Use of a large space structure as an orbital depot  
for hazardous wastes [IAF PAPER 79-209] p0039 A79-53359  
Large geostationary communications platform  
[IAF PAPER 79-210] p0010 A79-53360  
Distributed control of two typical flexible  
structures [IAF PAPER 79-212] p0010 A79-53362  
Multi-cell satellite for the communications of  
year 2000 [IAF PAPER 79-301] p0003 A79-53405  
Manned remote work station - Safety and rescue  
considerations [IAF PAPER 79-A-10] p0027 A79-53421  
Employment of large structure communications  
satellites for emergency calls [IAF PAPER 79-A-34] p0001 A79-53433  
Geometric model and analysis of rod-like large  
space structures [NASA-CR-158569] p0008 A79-21128  
Environmental interaction implications for large  
space systems p0008 A79-24027  
Space Construction Automated Fabrication  
Experiment Definition Study (SCAFIDS), part 3.  
Volume 2: Study results [NASA-CR-160288] p0011 A79-29203  
Space fabrication demonstration system, technical  
volume [NASA-CR-161286] p0011 A79-29211  
Space fabrication demonstration system: executive  
summary --- for large space structures  
[NASA-CR-161287] p0011 A79-29214  
Space construction system analysis, Part 1:  
Executive summary [NASA-CR-160295] p0004 A79-30266  
Space construction system analysis, Part 1:  
Executive summary. Special emphasis studies  
[NASA-CR-160298] p0004 A79-30269  
Platforms in space: Evolutionary trends  
p0005 A79-30879  
Winston solar concentrators and evaluation  
support, Phase 2: Non-imaging concentrators  
for space applications [NASA-CR-162279] p0004 A79-31764  
Load concentration due to missing members in  
planar faces of a large space truss  
[NASA-TT-1522] p0008 A79-33500  
**LARGE SPACE TELESCOPE**  
Stabilization of the shape of a deploying surface  
--- for large space radio telescope p0017 A79-50681  
**LASER APPLICATIONS**  
Solar-pumped lasers for space power transmission  
[AIAA PAPER 79-1015] p0017 A79-38202  
New energy conversion techniques in space,  
applicable to propulsion --- powering of  
aircraft with laser energy from SPS  
[AIAA PAPER 79-1338] p0037 A79-60490  
Potential of lasers for SPS power transmission  
[NASA-CR-157432] p0002 A79-23456  
**LASER OUTPUTS**  
Space Laser Power System --- for satellite solar  
power station transmission to earth  
[AIAA PAPER 79-1013] p0036 A79-38201  
**LASER PLASMAS**  
Anomalous intensity ratios of the resonance to  
intercombination lines of He-like ions in He-  
and CO<sub>2</sub>-laser-produced plasmas p0007 A79-24021  
**LASER RANGE FINDERES**  
A self pulsed laser ranging system under  
development at 'JPL' --- for onboard measurement  
of large space deployable reflector surface  
distortions [AIAA 79-0934] p0013 A79-34752  
**LASERS**  
RT CARBON DIOXIDE LASERS  
PT CONTINUOUS WAVE LASERS  
WT IMPULSED LASERS  
WT SPONTANEOUS LASERS  
WT PULSED LASERS  
**LASING**  
New methods for the conversion of solar energy to  
D. F. and laser power [AIAA PAPER 79-1436] p0036 A79-38886  
**LAUNCH VEHICLE CONFIGURATIONS**  
Deployable multi-payload platform  
[AIAA 79-0928] p0009 A79-34748  
**LAUNCH VEHICLES**  
WT STAFF LIFT LAUNCH VEHICLES  
**LAUNCHING**  
WT SPACECRAFT LAUNCHING  
**LDMP**  
A LONG DURATION EXPOSURE FACILITY  
**LIDARATION**  
General dynamics of a large class of flexible  
satellite systems [IAF PAPER 79-192] p0008 A79-53386  
**LIFE (DURABILITY)**  
WT FATIGUE LIFE  
**LIFE CYCLE COSTS**  
Design and operations technologies - Integrating  
the pieces --- for future space systems design  
[AIAA 79-0958] p0001 A79-34702  
**LIFE SUPPORT SYSTEMS**  
Concept definition for an extended duration  
orbiter RC155 [NASA-CR-160184] p0009 A79-23466  
**LIGHTNING**  
Platforms in space: Evolutionary trends  
p0005 A79-30879  
**LIQUID PROPELLANT ROCKET ENGINES**  
WT HYDRAZINE ENGINES  
**LOAD FACTORS**  
N LOADS (FORCES)  
**LOADING FORCES**  
N LOADS (FORCES)  
**LOADING WAVES**  
N LOADS (FORCES)  
**LOADS (FORCES)**  
Load concentration due to missing members in



planar faces of a large space truss  
[NASA-TP-1522] p0008 879-13500

**LONG DURATION EXPOSURE FACILITY**  
LEEF transverse flat plate heat pipe experiment  
/ST005/ --- Long Duration Exposure Facility  
[AIAA 79-1577] p0033 879-30053

**LONG TERM EFFECTS**  
Materials evaluation for use in long-duration  
space missions  
p0024 879-43307

**LONGITUDINAL CONTROL**  
Stability analysis of a flexible spacecraft with a  
sampled-data attitude sensor  
p0007 879-34516

**LOW THRUST PROPULSION**  
**WT ION PROPULSION**  
**WT SOLAR ELECTRIC PROPULSION**  
Space propulsion technology overview  
[AIAA 79-0860] p0029 879-34704  
Low-thrust chemical orbit transfer propulsion  
[AIAA PAPER 79-1582] p0030 879-34815  
The inclination change for solar sails and low  
earth orbit  
[AAS PAPER 79-104] p0030 879-47204  
Low-thrust chemical orbit transfer propulsion  
[NASA-79-79190] p0031 879-25129

**LOW**  
**U LARGE SPACE TELESCOPE**

**LOWAR SOIL**  
Cool comparisons for the use of nonterrestrial  
materials in space manufacturing of large  
structures  
[IAP PAPER 79-111] p0030 879-51302

## M

**MACHINERY**  
Space fabrication demonstration system, technical  
volume  
[NASA-CR-161286] p0011 879-29213  
Space fabrication demonstration system: Executive  
summary --- for large space structures  
[NASA-CR-161287] p0011 879-29214

**MAGNETIC DISTURBANCES**  
**WT MAGNETIC STORMS**  
**MAGNETIC EFFECTS**  
Plasma particle trajectories around spacecraft  
propelled by ion thrusters  
p0031 879-24029

**MAGNETIC METALS**  
**U METALS**  
**MAGNETIC PROPERTIES**  
**WT MAGNETIC EFFECTS**  
**MAGNETIC SHIELDING**  
Magnetic shielding of large high-power-satellite  
solar arrays using internal currents  
p0043 879-24026

**MAGNETIC STORMS**  
A combined spacecraft charging and pulsed E-ray  
simulation facility  
p0050 879-24054

**MAGNETIC SUBSTANCES**  
**U MAGNETIC STORMS**  
**MAGNETOACUSTICS**  
**U MAGNETOACUSTICS**  
**MAGNETOFLUIDDYNAMICS**  
Inductive energy storage for MPD thrusters  
[AIAA 79-0863] p0029 879-34716

**MAGNETOPLASMA DYNAMICS**  
**U MAGNETOFLUIDDYNAMICS**  
**MAINTENANCE**  
**WT SPACE MAINTENANCE**  
**MAN MACHINE SYSTEMS**  
Advanced teleoperators --- remote manipulation  
system  
p0027 879-34982  
Construction in space - Toward a fresh definition  
of the man/machine relation  
p0027 879-34985

**MANAGEMENT METHODS**  
Satellite Power System (SPS) financial management  
scenario  
[NASA-CR-157410] p0043 879-23502

**MANEUVERS**  
**WT EARTH ORBITAL MANEUVERS**  
**WT ORBITAL MANEUVERS**  
**WT SPACECRAFT DOCKING**  
**WT SPACECRAFT MANEUVERS**

**MANIPULATION**  
**U MANIPULATORS**  
**MANIPULATORS**  
Space manipulators - Present capability and future  
potential --- space shuttle remote handling system  
[AIAA 79-0903] p0027 879-34731  
Advanced teleoperators --- remote manipulation  
system  
p0027 879-34982  
Autonomous mechanical assembly on the space  
shuttle: An overview  
[NASA-CR-150010] p0028 879-28201

**MANNED ORBITAL SPACE STATIONS**  
**U ORBITAL SPACE STATIONS**  
**MANNED SPACE FLIGHT**  
Manned remote work station - Safety and rescue  
considerations  
[IAP PAPER 79-119] p0027 879-53421

**MANNED SPACECRAFT**  
**WT MANNED SPACECRAFT**  
**WT ORBITAL SPACE STATIONS**  
**WT ORBITAL WORKSHOPS**  
**WT ORBITAL J**  
**WT SPACE BASE COMMAND CENTER**  
**WT SPACE SHUTTLES**  
**WT SPACE STATIONS**

**MANUFACTURING**  
**WT SPACE MANUFACTURING**

**MAPPING**  
**WT DDTL MAPPING**  
**MATERIALS HANDLING**  
**WT REMOTE HANDLING**  
**MATERIALS SCIENCE**  
The enigma of the nightmarish 'environment',  
economics, energy: Proceedings of the  
Twenty-fourth National Symposium and Exhibition,  
San Francisco, Calif., May 8-10, 1979, Book 1 & 2  
p0023 879-43220

**MATHEMATICAL MODELS**  
Stability bounds for the control of large space  
structures  
p0014 879-43699

**MEASURING INSTRUMENTS**  
**WT ATTITUDE INDICATORS**  
**WT LASER RANGE FINDERS**  
**WT MICROWAVE RADIOMETERS**  
**WT OPTICAL MEASURING INSTRUMENTS**  
**WT SATELLITE-BORNE INSTRUMENTS**

**MECHANICAL DEVICES**  
The 13th Aerospace Mechanisms Symposium  
[NASA-CR-2001] p0046 879-32590

**MECHANICAL MEASUREMENT**  
**WT VIBRATION MEASUREMENT**  
**MECHANICAL PROPERTIES**  
**WT ADHESION**  
**WT DIMENSIONAL STABILITY**  
**WT FATIGUE LIFE**  
**WT FIBER STRENGTH**  
**WT FIBRE PROPERTIES**  
Graphite fiber reinforced glass matrix composites  
for aerospace applications  
p0023 879-43214

**MEETINGS**  
**U CONFERENCES**  
**MEMBRANE ANALOGY**  
**U MEMBRANE STRUCTURES**  
**U STRUCTURAL ANALYSIS**  
**MEMBRANE STRUCTURES**  
Electrostatically formed antennas ---  
Electrostatically Controlled Membrane Mirror for  
space applications  
[AIAA 79-0922] p0013 879-34743  
Nonreflective boundary control of a vibrating string  
--- application to electrostatically controlled  
large space membrane mirror antenna  
[AIAA 79-0950] p0013 879-34743

**MEMBRANE THEORY**  
**U STRUCTURAL ANALYSIS**  
**MEMBRANES**  
**WT MEMBRANE STRUCTURES**  
Study of membrane reflector technology  
[NASA-CR-150729] p0018 879-27655

**MERCURY ION ENGINE**  
Increased capabilities of the 30-cm diameter Hg  
ion thruster  
[AIAA 79-0910] p0030 879-34774

**MERCURY SPACECRAFT**  
Solar thermoelectric power generation for Mercury  
orbiter missions

- [AIAA 79-0995] p0029 A79-34730
- WSES**  
A nonlinear stress-strain law for or' allic meshes  
--- for large space antennas  
[AIAA 79-0996] p0029 A79-34730
- METAL MATRIX COMPOSITES**  
Satellite applications of metal-matrix composites  
p0029 A79-34731  
The application of metal-matrix composites to  
spaceborne parabolic antennas  
p0029 A79-34732
- METAL SHEETS**  
Thermally stable, thin, flexible  
graphite-fiber/aluminum sheet  
p0029 A79-34733
- METAL WORKING**  
NT SILICON (DRAFTING)  
**METALLIZATION**  
NT SILICON  
**METALLURGY**  
A nonlinear stress-strain law for metallic meshes  
--- for large space antennas  
[AIAA 79-0996] p0029 A79-34734
- METALS**  
NT METAL MATRIX COMPOSITES  
New highly conducting coordination compounds  
[AD-A064735] p0040 A79-22261
- MICROWAVE COMPRESSION TESTS**  
D MECHANICAL PROPERTIES  
**MICROPROCESSORS**  
A programmable power processor for a 25-KW power  
module  
[NASA-TN-78215] p0029 A79-24441
- MICROWAVE ANTENNAS**  
NT RECTENNAS  
Large multibeam space antennas  
[AIAA 79-0942] p0030 A79-34735  
Lightweight deployable microwave satellite  
antennas - Need, concepts and related technology  
problems  
[IAF PAPER 79-211] p0030 A79-51361
- MICROWAVE EQUIPMENT**  
NT ELECTRONICS  
NT MICROWAVE ANTENNAS  
NT MICROWAVE RADIOFREQUENCIES  
NT RECTENNAS
- MICROWAVE SPACECRAFTS**  
A Microwave Radiometer Spacecraft, some control  
requirements and concepts  
[AIAA 79-1777] p0002 A79-45423
- MICROWAVE TRANSMISSION**  
A development strategy for the solar power satellite  
[AAS PAPER 79-154] p0035 A79-21246  
Status of the SPS concept development and  
evaluation program --- Solar Power Satellite  
p0035 A79-31949  
Solar Power Satellite system definition  
p0035 A79-31920  
A review of some critical aspects of satellite  
power systems  
p0035 A79-31921  
Solar power satellites - Microwaves deliver the  
power  
p0037 A79-30370  
Energy for the year 2000 - The SPS concept  
p0038 A79-46026  
The technology base for the microwave power  
transmission system in the SPS  
p0038 A79-51943  
Solar thermal aerostat research station /STARS/  
[IAF PAPER 79-35] p0051 A79-53261  
Space-based solar power conversion and delivery  
systems study. Volume 3: Microwave power  
transmission studies  
[NASA-CN-150294] p0040 A79-22619  
Satellite Power Systems (SPS) concept definition  
study exhibit C. Volume 3: Experimental  
verification definition  
[NASA-CN-161214] p0041 A79-22632  
Satellite Power Systems (SPS) concept definition  
study, exhibit C. Volume 5: Special emphasis  
studies  
[NASA-CN-161215] p0041 A79-22633  
Satellite Power Systems (SPS) concept definition  
study, exhibit C. Volume 4: In-depth element  
investigation  
[NASA-CN-161216] p0041 A79-22634  
Preliminary environmental assessment for the  
Satellite Power System (SPS). Volume 2:
- Detailed assessment  
[NASA-TN-80355] p0042 A79-24438  
Satellite Power Systems (SPS) resource requirements  
(critical materials, energy, and land)  
[NASA-CN-162390] p0044 A79-31254
- MICROWAVE TUBES**  
NT ELECTRONICS  
**MINIMIZATION**  
D OPTIMIZATION  
**MIRRORS**  
Electrostatically formed antennas ---  
Electrostatically Controlled Membrane Mirror for  
space applications  
[AIAA 79-0922] p0031 A79-34743  
Nonreflective boundary control of a vibrating string  
--- application to electrostatically controlled  
large space membrane mirror antennas  
[AIAA 79-0950] p0031 A79-34743
- MISSION PLANNING**  
An evolutionary solar power satellite program  
[AAS PAPER 79-153] p0035 A79-21265  
A development strategy for the solar power satellite  
[AAS PAPER 79-154] p0035 A79-21266  
Preliminary mission requirements, technology and  
design considerations for a solar electric  
propulsion stage  
[AIAA 79-0908] p0029 A79-34735  
Deployable antenna technology development for the  
Large Space Systems Technology program  
[AIAA 79-0932] p0009 A79-34750  
Technical challenges of large space systems in the  
21st century  
[AAS 79-195] p0001 A79-34848  
Planning Space Shuttle's maiden voyage  
p0042 A79-44248  
Dynamic qualification of large space  
structures by means of modal coupling techniques  
[IAF PAPER 79-107] p0008 A79-51299  
Some activities and vehicle concepts envisioned  
for future earth orbital missions  
p0003 A79-22325  
Pointing and control system enabling technology  
for future automated space missions  
[NASA-CN-150513] p0038 A79-22377  
Space station thermal control surfaces --- space  
radiators  
[NASA-CN-161217] p0008 A79-22378  
Mission specification for three generic mission  
classes  
[NASA-CN-159849] p0004 A79-21326
- MIRRORS**  
NT METAL MATRIX COMPOSITES  
**MODAL RESPONSE**  
Dynamic qualification of large space structures by  
means of modal coupling techniques  
[IAF PAPER 79-107] p0008 A79-51299
- MODE OF VIBRATION**  
D VIBRATION MODE  
**MODE SHAPES**  
D MODAL RESPONSE  
**MODELS**  
NT DYNAMIC MODELS  
NT MATHEMATICAL MODELS  
**MODULES**  
NT VIBRATION MODE  
**MODULES**  
NT POWER MODULES (SPS)  
NT SERVICE MODULES  
NT SPACECRAFT MODULES  
MOSECO: A potential European contribution in  
developing large solar generators suitable for  
growing power levels up to SPS-systems  
p0044 A79-30752
- MOISTURE CONTENT**  
Moisture effects on spacecraft structures  
p0023 A79-43302
- MORSTON**  
NT ANGULAR MORSTON  
**MOSS (SPACE STATIONS)**  
D CAPITAL SPACE STATIONS  
**MOTION EQUATIONS**  
D EQUATIONS OF MOTION  
**MOTION STABILITY**  
NT SPACECRAFT STABILITY  
**MULTILAYER INSULATION**  
Orbital Test Satellite (OTS) thermal design and  
in-orbit performance  
p0051 A79-31270

MULTILAYER STRUCTURES  
O LAMINATES

## N

## NASA PROGRAMS

- Solar Power Satellite system Definition  
p0015 A79-19920
- First steps to the Solar Power Satellite  
p0016 A79-32721
- Deployable antenna technology development for the  
Large Space Systems Technology program  
[AIAA 79-0932] p0009 A79-34750
- Maypole /Noo/Colum/ deployable reflector concept  
development for 10 to 100 meter antennas  
[AIAA 79-0935] p0009 A79-34753
- The future United States space program:  
Proceedings of the Twenty-fifth Anniversary  
Conference, Houston, Tex., October 30-November  
2, 1978, Parts 1 & 2 p0048 A79-34860
- Results from Symposium on Future Critical Power  
Systems Technology Requirements p0036 A79-51091
- A technology base for near-term space platforms  
[IAF PAPER 79-110] p0062 A79-51300
- Automatic in-orbit assembly of large space  
structures p0026 A79-22562
- Development of a beam builder for automatic  
fabrication of large composite space structures  
p0011 A79-22563
- NASA authorization for fiscal year 1980, part 2  
[CPO-83-135] p0050 A79-25627
- NASA authorization for fiscal year 1980, part 3  
[CPO-84-085] p0050 A79-26043
- NASA authorization, 1980, volume 1, part 1  
[CPO-86-422] p0050 A79-31084
- NASA authorization, 1980, volume 1, part 4  
[CPO-86-423] p0050 A79-31085
- NAVIGATION INSTRUMENTS
- NT ATTITUDE INDICATORS
- NOCTURNAL LASERS
- Anomalous intensity ratios of the resonance to  
intercombination lines of He-like ions in He-  
and CO<sub>2</sub>-laser-produced plasmas p0047 A79-24021

## NIMPH (NIMPH)

## N HYDRAINE ENGINES

## NITROGEN COMPOUNDS

## NT POLYIMIDES

## NONSTATIONARY PROCESSES

## O OAT TRANSFER

## NONREFLECTION

## O ENERGY ABSORPTION

## NUCLEAR AUXILIARY POWER UNITS

## NT SPACE POWER REACTORS

## NUCLEAR ELECTRIC POWER GENERATION

## NT SPACE POWER REACTORS

- System definition space-based power conversion  
systems --- for satellite power transmission to  
earth [AIAA-CP-150268] p0041 A79-23483

## NUCLEAR POWER GENERATION

## O NUCLEAR ELECTRIC POWER GENERATION

## NUCLEAR POWER REACTORS

## NT SPACE POWER REACTORS

## NUCLEAR REACTORS

## NT SPACE POWER REACTORS

## NUMERICAL ANALYSIS

## NT TROOP ANALYSIS

## NUMERICAL CONTROL

- Advanced teleoperators --- remote manipulation  
system p0027 A79-34902

## NUMERICAL STABILITY

- Stability bounds for the control of large space  
structures p0014 A79-41099

## O

## OBSERVATION

## NT EARTH OBSERVATIONS (FROM SPACE)

## OPT

## O SPACE TRANSPORTATION SYSTEM FLIGHTS

## ONBOARD COMPUTERS

## O AIRBORNE/SPACEBORNE COMPUTERS

## ONBOARD EQUIPMENT

- NT AIRBORNE/SPACEBORNE COMPUTERS
- NT SPACECRAFT ELECTRONIC EQUIPMENT

## OPTICAL EQUIPMENT

## NT ASTROCHEMICAL TELESCOPES

## NT OPTICAL MEASURING INSTRUMENTS

## OPTICAL METROLOGY

- A family of sensors for the sensing of the  
position and vibration of spacecraft structures  
[AIAA 79-1749] p0015 A79-45383

## OPTICAL MEASURING INSTRUMENTS

- Surface accuracy measurement system deployable  
reflector antennas [AIAA 79-0937] p0013 A79-34755

## OPTICAL PUMPING

- Solar-pumped lasers for space power transmission  
[AIAA PAPER 79-0095] p0037 A79-38202

## OPTICAL RANGE FINDERS

## NT LASER RANGE FINDERS

## OPTICAL SENSORS

## O OPTICAL MEASURING INSTRUMENTS

## OPTICAL CONTROL

- Control of large space structures using  
equilibrium enforcing optimal control  
[AIAA 79-0927] p0013 A79-34747
- Nonreflective boundary control of a vibrating string  
--- application to electrostatically controlled  
large space membrane mirror antennas  
[AIAA 79-0950] p0013 A79-34743
- Attitude control of agile flexible spacecraft  
[AIAA 79-1739] p0015 A79-45381
- Optimal local control of flexible structures ---  
for space structures [AIAA 79-1740] p0015 A79-45382
- Orthogonal subspace reduction of optimal regulator  
order --- for spacecraft structural vibration  
[AIAA 79-1742] p0015 A79-45384
- Large angle maneuver strategies for flexible  
spacecraft [AAS PAPER 79-156] p0016 A79-47235
- Flexible spacecraft control by model error  
sensitivity suppression p0017 A79-49033
- On cost-sensitivity controller design methods for  
uncertain dynamic system p0017 A79-49035

## OPTIMIZATION

## NT OPTIMAL CONTROL

- Application of Lagrange Optimization to the drag  
polar utilizing experimental data  
[AIAA PAPER 79-1033] p0014 A79-49335

## OPTIMUM CONTROL

## O OPTIMAL CONTROL

## ORBIT CALCULATION

- Assessment of the errors of an analytical method  
of calculating the geocentric trajectories of a  
solar sail p0016 A79-53063

## ORBIT PERTURBATION

## NT SATELLITE PERTURBATION

## ORBIT TRANSFER VEHICLES

- A space-based orbital transfer vehicle - Bridge to  
the future [AIAA 79-0865] p0047 A79-34705
- Orbit transfer vehicle propulsion for transfer of  
Shuttle-deployed large spacecraft to  
geosynchronous orbit [AIAA 79-0880] p0029 A79-34716
- Preliminary design for a space based orbital  
transfer vehicle [AIAA 79-0907] p0048 A79-34720
- Is a versatile orbit transfer stage feasible ---  
Orbit Transfer Vehicle concepts, potential  
missions and evolution [AIAA 79-0866] p0029 A79-34772
- Orbit transfer needs of the late 1980s and the 1990s  
[IAF PAPER 79-30] p0049 A79-51256

## ORBITAL ASSEMBLY

- Thermal control design analysis of an on-orbit  
assembly spacecraft [AIAA 79-0917] p0007 A79-34740
- Expandable modules for large space structures  
[AIAA 79-0924] p0009 A79-34745
- Large space system automated assembly technique  
[AIAA 79-0939] p0027 A79-34757
- Long interface docking for large space structure  
assembly [AIAA 79-0954] p0014 A79-34745

Space structure - A key to new opportunities ---  
 deployable antenna and construction/servicing  
 system  
 [NAS PAPER 79-059] p0001 879-36549

On-orbit assembly of large Space Structures /LSS/  
 using an autonomous rendezvous and docking  
 [NAS PAPER 79-100] p0027 879-47201

Construction of large space structures  
 [IAP PAPER 79-106] p0010 879-53298

Orbital demonstration - The prelude to large  
 operational structures in space  
 [IAP PAPER 79-207] p0002 879-53357

Automatic in-orbit assembly of large space  
 structures  
 p0029 879-22562

Autonomous mechanical assembly on the space  
 shuttle: An overview  
 [NASA-CR-150910] p0028 879-28201

Space Construction Automated Fabrication  
 Experiment Definition Study (SCAFEDS), part 1.  
 Volume 2: Study results  
 [NASA-CR-160200] p0011 879-29203

Space construction system analysis. Part 1:  
 Executive summary  
 [NASA-CR-160295] p0004 879-30766

**ORBITAL ELEMENTS**

The inclination change for solar sails and low  
 earth orbit  
 [NAS PAPER 79-104] p0030 879-47208

**ORBITAL FLIGHT TESTS (SHUTTLE)**

8 SPACE TRANSPORTATION SYSTEM FLIGHTS

**ORBITAL MANEUVERS**

Payload capacity of Ariane launched geostationary  
 satellites using an electric propulsion system  
 for orbit raising  
 [IAP PAPER 79-32] p0070 879-51250

**ORBITAL RENDEZVOUS**

NT FASTR ORBITAL RENDEZVOUS

**ORBITAL SPACE STATIONS**

NT LONG DURATION EXPERIMENT FACILITY

NT ORBITAL WORKSHOPS

NT ORVLAD 3

Space-based radio telescopes and an orbiting  
 deep-space relay station  
 [AIAA 79-0967] p0009 879-34762

The possibilities of STTI from space  
 p0002 879-10459

Orbital demonstration - The prelude to large  
 operational structures in space  
 [IAP PAPER 79-207] p0002 879-53357

An economic analysis of a commercial approach to  
 the design and fabrication of a space power system  
 [NASA-TN-79157] p0040 879-22193

Space construction base control system  
 [NASA-CR-161200] p0010 879-29295

**ORBITAL TEST SATELLITE (OTS)**

8 OTS (ESA)

**ORBITAL TRANSFER**

8 TRANSFER ORBITS

**ORBITAL WORKSHOPS**

Manned remote work station - Safety and resource  
 considerations  
 [IAP PAPER 79-8-99] p0017 879-13021

**ORBITING SATELLITES**

8 ARTIFICIAL SATELLITES

**ORBITS**

NT CIRCULAR ORBITS

NT PARABOLIC ORBITS

NT CONFINED ORBITS

NT SATELLITE ORBITS

NT SPACECRAFT ORBITS

NT TRANSFER ORBITS

**OTS (ESA)**

Attitude control by solar sailing - A precision  
 experiment with OTS-2  
 p0014 879-36109

Effects of electron irradiation on large  
 insulating surfaces used for European  
 Communications Satellites  
 p0013 879-36190

Orbital Test Satellite (OTS) thermal design and  
 in-orbit performance  
 p0051 879-31270

Orbital assessment of OTS thermal performance  
 p0051 879-31271

The OTS hydrazine reaction control system thermal  
 conditioning technique  
 p0051 879-31304

## OTV

8 ORBIT TRANSFER VEHICLES

## OUTPUT

81 LASER OUTPUTS

P

## PARABOLIC ANTENNAS

Post-fabrication contour adjustment for precision  
 parabolic reflectors --- for outer space use  
 [AIAA 79-0933] p0009 879-34751

A self pulsed laser ranging system under  
 development at 'JPL' --- for onboard measurement  
 of large space deployable reflector surface  
 distortions  
 [AIAA 79-0934] p0013 879-34752

Raypole /Roop/Columa/ deployable reflector concept  
 development for 30 to 100 meter antennas  
 [AIAA 79-0935] p0009 879-34753

Surface accuracy measurement system deployable  
 reflector antennas  
 [AIAA 79-0937] p0013 879-34755

An approach toward the design of large diameter  
 offset-fed antennas --- wrap-rib space antennas  
 [AIAA 79-0938] p0010 879-34754

Large multibeam space antennas  
 [AIAA 79-0942] p0010 879-34756

The application of metal-matrix composites to  
 spaceborne parabolic antennas  
 p0024 879-41322

Thermally stable, thin, flexible  
 graphite-fiber/aluminum sheet  
 p0024 879-41323

## PARABOLIC REFLECTORS

Electrostatically formed antennas ---  
 Electrostatically Controlled Membrane Mirror for  
 space applications  
 [AIAA 79-0922] p0013 879-34743

Large solid deployable reflector --- for satellite  
 radio telescopes  
 [AIAA 79-0925] p0009 879-34746

Post-fabrication contour adjustment for precision  
 parabolic reflectors --- for outer space use  
 [AIAA 79-0933] p0009 879-34751

Geometric model and analysis of rod-like large  
 space structures  
 [NASA-CR-150509] p0008 879-23126

Winter solar concentrators and evaluation  
 support. Phase 2: Non-imaging concentrators  
 for space applications  
 [NASA-CR-162279] p0044 879-31244

## PARTICLE ACCELERATORS

NT ION ACCELERATORS

## PARTICLE DENSITY (CONCENTRATION)

NT PLASMA DENSITY

## PARTICLE INTERACTIONS

Spacecraft Charging Technology, 1978

[NASA-CR-2071] p0050 879-24001

## PARTICLE TRAJECTORIES

Plasma particle trajectories around spacecraft

propelled by ion thrusters  
p0011 879-24024

## PARTICLES

NT CHARGED PARTICLES

NT FREE ELECTRONS

NT HELIUM PLASMA

NT LANTH PLASMA

NT PLASMA SHEATHS

NT THERMAL PLASMAS

## PAYLOAD DELIVERY (STS)

Orbit transfer needs of the late 1980s and the 1990s

[IAP PAPER 79-10] p0049 879-53256

## PAYLOAD RETRIEVAL (STS)

Teleoperator system for management of satellite

deployment and retrieval  
p0027 879-40535

## PAYLOADS

8 SPACE SHUTTLE PAYLOADS

Payload capacity of Ariane launched geostationary

satellites using an electric propulsion system

for orbit raising  
[IAP PAPER 79-12] p0030 879-53250

## PERFORMANCE SUBSECTION

Materials evaluation for use in long-duration

space missions  
p0024 879-41307

Optimal local control of flexible structures ---

for space structures  
[AIAA 79-1740] p0075 879-45382

**PROTUBERANCE**  
 NT SATELLITE PERTURBATION  
**PHOTOCOPYING**  
 U ELECTRIC COPYING  
**PHOTOVOLTAIC CELLS**  
 NT PHOTOVOLTAIC CELLS  
**PHOTOVOLTAIC EFFECTS**  
 U TEMPERATURE EFFECTS  
**PHOTOVOLTAIC CELLS**  
 Photovoltaic generators in space --- conference,  
 ESTEC, Netherlands, Sep. 1978  
 [SP-140] p0044 879-30710  
 Winston solar concentrators and evaluation  
 support, Phase 2; Net-imaging concentrators  
 for space applications  
 [NASA-CR-912279] p0044 879-31764

**PIVOT ATTITUDE CONTROL**  
 U LONGITUDINAL CONTROL  
**PLANTARY EXPLORATION**  
 U SPACE EXPLORATION  
**PLANTARY SPACECRAFT**  
 U INTERPLANETARY SPACECRAFT  
**PLANTYOCENTRIC COORDINATES**  
 NT UROCENTRIC COORDINATES  
**PLANNING**  
 NT SWEPT FORWARD WING  
**PLANNING**  
 NT MISSION PLANNING  
**PLASMA DENSITY**  
 Anomalous intensity ratios of the resonance to  
 intercombination lines of He-like ions in Nd-  
 and CO<sub>2</sub>-laser-produced plasma p0047 879-24021

**PLASMA ENGINES**  
 Inductive energy storage for MPD thrusters  
 [AIAA 79-0861] p0029 879-34760

**PLASMA INTERACTIONS**  
 Effects of plasma sheath on solar power satellite  
 array  
 [AIAA PAPER 79-1507] p0037 879-06699  
 Spacecraft charging technology, 1978  
 [NASA-CR-2079] p0050 879-24001  
 Magnetic shielding of large high-power-satellite  
 solar arrays using internal currents p0043 879-24026  
 Environmental interaction implications for large  
 space systems p0008 879-24027  
 Space environmental effects and the solar power  
 satellite p0043 879-24028  
 Plasma particle trajectories around spacecraft  
 propelled by ion thrusters p0031 879-24029

**PLASMA LAYERS**  
 NT PLASMA SHEATHS  
**PLASMA POWER SOURCES**  
 NT PLASMA ENGINES  
**PLASMA SHEATHS**  
 Effects of plasma sheath on solar power satellite  
 array  
 [AIAA PAPER 79-1507] p0037 879-06699  
 Plasma sheath effects and voltage distributions of  
 large high-power satellite solar arrays p0043 879-24024

**PLASMA SPECTRA**  
 Anomalous intensity ratios of the resonance to  
 intercombination lines of He-like ions in Nd-  
 and CO<sub>2</sub>-laser-produced plasma p0047 879-24021

**PLASMAS (PHYSICS)**  
 NT IONOSPHERIC PLASMA  
 NT LASER PLASMAS  
 NT THERMAL PLASMAS  
**PLASTIC FILMS**  
 U POLYMERIC FILMS  
**PLASTICS**  
 NT CARBON FIBER REINFORCED PLASTICS  
**PLATFORMS**  
 A technology team for near-term space platform  
 [IAP PAPER 79-110] p0002 879-51300

**PLUMES**  
 NT ROCKET EXHAUST  
**POINTING CONTROL SYSTEMS**  
 Attitude control requirements for future space  
 systems  
 [AIAA 79-0951] p0014 879-34767  
 The dual moment control device for large space  
 systems - An example of distributed systems

adaptive control p0014 879-41904  
 Pointing and control system enabling technology  
 for future automated space missions  
 [NASA-CR-150513] p0010 879-22177

**POLICIES**  
 NT PUBLIC POLICY  
**POLYIMIDE RESINS**  
 Graphite/Polyimide Composites --- conference on  
 Composites for Advanced Space Transportation  
 Systems  
 [NASA-CR-2079] p0025 879-30297  
 Fabrication of structural elements --- using  
 graphite/PMR-15 p0025 879-30304

**POLYIMIDES**  
 Graphite/Polyimide Composites --- conference on  
 Composites for Advanced Space Transportation  
 Systems  
 [NASA-CR-2079] p0025 879-30297  
 Graphite/polyimides state-of-the-art panel  
 discussion p0025 879-30320

**POLYMER MATRIX COMPOSITE MATERIALS**  
 Design fabrication and test of graphite/polyimide  
 composite joints and attachments for advanced  
 aerospace vehicles  
 [NASA-CR-150000] p0017 879-24044  
 Graphite/Polyimide Composites --- conference on  
 Composites for Advanced Space Transportation  
 Systems  
 [NASA-CR-2079] p0025 879-30297  
 Fabrication of structural elements --- using  
 graphite/PMR-15 p0025 879-30304

**POLYMERIC FILMS**  
 Space radiation effects on spacecraft materials  
 p0024 879-41306

**POSITIONING SERVICES (NAVIGATION)**  
 NT DOCS (NAVIGATION)  
**POTENTIAL ENERGY**  
 NT ELECTRIC POTENTIAL  
**POTENTIAL THEORY**  
 The calculation of spacecraft potential;  
 Comparison between theory and observation  
 p0050 879-24014

**POWER CONCENTRATION**  
 Synchronous orbit power technology needs  
 [NASA-TN-80280] p0008 879-22174  
 Primary electric propulsion for future space  
 mission  
 [NASA-TN-79941] p0010 879-22190

**POWER GENERATORS**  
 U ELECTRIC GENERATORS  
**POWER MODULES (SOLAR)**  
 A programmable power processor for a 25-kW power  
 module  
 [NASA-TN-78215] p0021 879-24441

**POWER PROCESSING SYSTEMS**  
 U POWER CONCENTRATION  
**PROJECTIONS**  
 NT PERFORMANCE PROJECTION  
**PROJECTIONS**  
 U STATISTICAL EQUIPMENT  
**PROJECT DEVELOPMENT**  
 NT WEAPONS DEVELOPMENT  
**PROGRAMMING LANGUAGES**  
 NT FORTRAN  
**PROGRAMS**  
 NT PROPER SPACE PROGRAMS  
 NT DATA PROGRAMS  
 NT PROJECT SETI  
 NT SPACE PROGRAMS  
**PROJECT SETI**  
 The possibilities of SETI from space  
 p0002 879-50459

**PROJECTS**  
 NT PROJECT SETI  
**PROPORTIONAL CONTROL**  
 Stability of  
 proportional-plus-derivative-plus-integral  
 control of flexible spacecraft  
 p0010 879-51945

**PROPULSION**  
 NT CHEMICAL PROPULSION  
 NT ELECTRIC PROPULSION  
 NT ION PROPULSION  
 NT LOW THRUST PROPULSION  
 NT SOLAR ELECTRIC PROPULSION



WT SPACECRAFT PROPELLION  
**PROPELLION SYSTEM CONCEPTS**  
 Primary electric propulsion for future space  
 missions  
 [NASA-TN-79141] p0020 879-22100  
**PROPELLION SYSTEM PERFORMANCE**  
 Inductive energy storage for MPD thrusters  
 [AIAA 79-0883] p0025 879-34712  
**PROTECTION**  
 WT ENVIRONMENT PROTECTION  
 WT THERMAL PROTECTION  
**POOLED LASERS**  
 A self-pumped laser ranging system under  
 development at JPL --- for onboard measurement  
 of large space deployable reflector surface  
 distortions  
 [AIAA 79-0934] p0013 879-34752  
**PTFE (Teflon)**  
 U POLYESTER GLASS  
**PTCHOPARALLOY**  
 U COMPOSITE MATERIALS

## R

**RADAR**  
 WT RADAR MEASUREMENT  
 WT SYNTHETIC APERTURE RADAR  
**RADAR MEASUREMENT**  
 Relative attitude of large space structures using  
 radar measurements  
 [AAS PAPER 79-155] p0016 879-47230  
**RADIATION DAMAGE**  
 Effects of electron irradiation on large  
 insulating surfaces used for European  
 Communications Satellites  
 p0023 879-36190  
 Space radiation effects on composite matrix  
 materials - Analytical approaches  
 p0023 879-41305  
 Materials degradation in space environments  
 [AIAA PAPER 79-1568] p0025 879-46700  
**RADIATION DISTRIBUTION**  
 WT ANTENNA RADIATION PATTERNS  
**RADIATION EFFECTS**  
 WT RADIATION DAMAGE  
 Space radiation effects on composite matrix  
 materials - Analytical approaches  
 p0023 879-41305  
 Effects of electron irradiation on large  
 insulating surfaces used for European  
 Communications Satellites  
 p0023 879-36190  
 Preliminary environmental assessment for the  
 Satellite Power System (SPS). Volume 2:  
 Detailed assessment  
 [NASA-TN-80355] p0043 879-24436  
**RADIATION HARDENING**  
 Solar photovoltaic research and development  
 program of the Air Force Aero Propulsion  
 Laboratory --- silicon solar cell applicable to  
 satellite power systems  
 p0045 879-32642  
**RADIATION HEATING INSTRUMENTS**  
 WT MICROWAVE RADIOMETERS  
**RADIO ANTENNAS**  
 WT MICROWAVE ANTENNAS  
 Space-based radio telescopes and an orbiting  
 deep-space relay station  
 [AIAA 79-0947] p0001 879-34762  
**RADIO AUTONOMY**  
 The possibilities of SRTI from space  
 p0002 879-50459  
**RADIO COMMUNICATION**  
 Feasibility study for a satellite frequency  
 modulated radio communication system  
 [NSA-CN(79)-1951-FCB-1] p0004 879-27376  
**RADIO EQUIPMENT**  
 WT RADIO ANTENNAS  
 WT RADIO TELESCOPES  
 WT SPACECRAFT ANTENNAS  
**RADIO PROPULSION**  
 New methods for the conversion of solar energy to  
 V. F. and laser power  
 [AIAA PAPER 79-1436] p0034 879-34044  
**RADIO PROPULSION UTILIZATION**  
 Effects of electron irradiation on large  
 insulating surfaces used for European  
 Communications Satellites  
 p0023 879-36190

**RADIO TELESCOPES**  
 Space-based radio telescopes and an orbiting  
 deep-space relay station  
 [AIAA 79-0947] p0001 879-34762  
 Stabilization of the shape of a deploying surface  
 --- for large space radio telescope  
 p0017 879-50459  
**RADIO TRANSMISSION**  
 WT IONOSPHERIC PROPAGATION  
 WT MICROWAVE TRANSMISSION  
**RADIOACTIVE WASTES**  
 Use of a large space structure as an orbital depot  
 for hazardous wastes  
 [IAP PAPER 79-204] p0039 879-51350  
**RADIOMETERS**  
 WT MICROWAVE RADIOMETERS  
**RANGE FINDERS**  
 WT LASER RANGE FINDERS  
**RANKING CYCLE**  
 Internally pumped Rankine cycle thermal transport  
 devices  
 [AIAA PAPER 79-1001] p0040 879-30040  
**RECOVERABLE SPACECRAFT**  
 WT RECOVERABLE SPACECRAFT  
 WT SPACE SHUTTLES  
**RESEARCH**  
 Solar power satellites - Microwaves deliver the  
 power  
 p0037 879-36374  
 Solar power satellite ground stations  
 p0037 879-44209  
**REFLECTOR ANTENNAS**  
 U REFLECTORS  
**REENTRY VEHICLES**  
 WT REENTRY SPACECRAFT  
**REFLECTORS**  
 WT PARABOLIC REFLECTORS  
 WT SOLAR REFLECTORS  
 Calculated scan characteristics of a large  
 spherical reflector antenna  
 p0007 879-37100  
 Stabilization of the shape of a deploying surface  
 --- for large space radio telescope  
 p0017 879-50459  
 Study of membrane reflector technology  
 [NASA-CN-750729] p0010 879-27655  
**REGULATORS**  
 Orthogonal subspace reduction of optical regulator  
 used --- for spacecraft structural vibration  
 [AIAA 79-1742] p0015 879-45308  
**REINFORCED MATERIALS**  
 U COMPOSITE MATERIALS  
**REINFORCING FIBERS**  
 WT CARBON FIBERS  
**RELATIONSHIPS**  
 WT STRESS-STRAIN RELATIONSHIPS  
**REMOTE CONTROL**  
 Teleoperator system for management of satellite  
 deployment and retrieval  
 p0027 879-40529  
**REMOTE HANDLING**  
 Space manipulators - Present capability and future  
 potential --- space shuttle remote handling system  
 [AIAA 79-0993] p0023 879-34712  
**REMOTE SENSORS**  
 Advanced teleoperators --- remote manipulation  
 system  
 p0027 879-34902  
 Mission specification for three generic mission  
 classes  
 [NASA-CN-750040] p0004 879-23126  
**RESEARCH**  
 WT EARTH ORBITAL RESEARCH  
**REPORTS**  
 WT CONCEPTUAL REPORTS  
**REQUIREMENTS**  
 Satellite Power Systems (SPS) concept definition  
 study, exhibit C. Volume 7: System/subsystem  
 requirements data book  
 [NASA-CN-761223] p0042 879-23009  
**RESCUE OPERATIONS**  
 Planned remote work station - Safety and rescue  
 considerations  
 [IAP PAPER 79-4-19] p0027 879-51421  
**RESEARCH AND DEVELOPMENT**  
 Energy and aerospace Proceedings of the  
 Anglo-American Conference, London, England,  
 December 5-7, 1978  
 p0035 879-31908



DATE/TIME: POWER TRANSMISSION (PT) PART 01

sampled-data attitude sensor  
attitude control by solar sailing - A promising  
experiment with OTS-2

Stability of  
proportional-plus-derivative-plus-integral  
control of flexible spacecraft

SATELLITE ATTITUDE RESTORANCE  
U SPACECRAFT STABILITY  
SATELLITE COMMUNICATIONS  
U SPACECRAFT COMMUNICATION  
SATELLITE CONTROL  
WT SATELLITE ATTITUDE CONTROL  
Telescope system for management of satellite  
deployment and retrieval

SATELLITE DESIGN		page 479-4839
An evolutionary color power satellite program		
[AES PAPER 79-157]	p0035	479-24265
Large Advanced Space System /LASS/ Computer Program		
[AES 79-090a]	p0007	479-34732
Satellite color power station designs with		
concentrators and radiating control		
[IAP PAPER 79-17a]	p0039	479-53136
General dynamics of a large class of flexible		
satellite systems		
[IAP PAPER 79-091]	p0008	479-3332a

SATELLITE LAUNCHING  
U SPACECRAFT LAUNCHING  
SATELLITE MANEUVERS  
U SPACECRAFT MANEUVERS  
SATELLITE NETWORKS  
Satellite clusters

The critical satellite technical issues of future  
pervasive broadband low-cost communication  
networks

SATELLITE ORBIT CALCULATION  
 N ORBIT CALCULATION  
 SATELLITE ORBITS  
 BY STODOLNICKSON ORBITS  
 A method of controlling orbits of geostationary  
 satellites with minimum fuel consumption  
 p0067 ATG-2070

**SATELLITE FERTURIZATION**  
A method of controlling orbits of geostationary  
satellites with minimum fuel consumption  
00047 179-50 RMZ

SATELLITE POWER TRANSMISSION (TO EARTH)	P0047 479-20962
A development strategy for the solar power satellite	P0048 479-21269
[AND PAPER 70-154]	
Status of the SPS concept development and evaluation program --- Solar Power Satellite	P0049 479-21979
Solar Power Satellite system definition	P0050 479-21980
A review of some critical aspects of power system	

power system

new methods for the conversion of solar energy to  
D. F. and laser power

[AIAA PAPERS 79-1876] p0034 479-35866

The Development of solar power satellites

p0034 479-35865

Space Laser Power System --- for satellite solar  
power station transmission to earth

[AIAA PAPERS 79-1013] p0034 479-36201

Solar-pumped lasers for space power transmission

[AIAA PAPERS 79-1015] p0037 479-36203

Solar power satellites - Microwaves deliver the  
power

Energy for the year 2000 - The EPS concept  
Computer modeling for a space power transmission system  
The technology base for the microwave power transmission system in the EPS  
Solar power satellites for Europe [IAP PAPER 79-173]  
A power transmission concept for a European EPS system

- Satellite power system: Concept development and evaluation program, reference system report [DOD/FA-0023] p0024 879-21510
- Space-based solar power conversion and delivery systems study, Volume 1: Executive summary [NASA-CR-150294] p0040 879-22617
- Space-based solar power conversion and delivery systems study, Volume 2: Engineering analysis [NASA-CR-150295] p0040 879-22618
- Space-based solar power conversion and delivery systems study, Volume 3: Microwave power transmission studies [NASA-CR-150296] p0040 879-22619
- Space-based solar power conversion and delivery systems study, Volume 4: Energy conversion systems studies [NASA-CR-150297] p0040 879-22620
- Satellite Power System (SPS) concept definition study exhibit C, Volume 1: Experimental verification definition [NASA-CR-161294] p0041 879-22632
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 1: Special emphasis studies [NASA-CR-161295] p0041 879-22633
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 1: In-depth element investigation [NASA-CR-161296] p0041 879-22634
- Systems definition space-based power conversion systems --- for satellite power transmission to earth [NASA-CR-150268] p0041 879-23403
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 1: Executive summary [NASA-CR-161294] p0041 879-23404
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 2, part 1: System engineering [NASA-CR-161299] p0041 879-23405
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 2, part 2: System engineering, cost and programming [NASA-CR-161220] p0042 879-23406
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 2, part 2: System engineering, cost and programming, appendices [NASA-CR-161221] p0042 879-23407
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 4: Transportation analysis [NASA-CR-161222] p0042 879-23408
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 5: System/subsystem requirements data book [NASA-CR-161223] p0042 879-23409
- Satellite Power System (SPS) resource requirements (critical materials, energy and land) [NASA-CR-150600] p0042 879-23412
- Potential of laser for SPS power transmission [NASA-CR-157432] p0042 879-23496
- Satellite Power System (SPS) mapping of exclusion areas for antenna sites [NASA-CR-157435] p0042 879-23499
- Satellite Power System (SPS) military implications [NASA-CR-157436] p0042 879-23500
- Satellite Power System (SPS) financial management scenario [NASA-CR-157438] p0043 879-23502
- Preliminary environmental assessment for the Satellite Power System (SPS), Volume 2: Detailed assessment [NASA-79-00355] p0043 879-24636
- Environmental factors of power satellites [SAMSO-18-79-06] p0043 879-24713
- Solar Power Satellite Research, Development, and Demonstration Program Act of 1978 [GPO-35-504] p0044 879-30726
- Solar power satellites: The Engineering Challenge p0044 879-30750
- Interface problems on an SPS solar array blanket p0044 879-30751
- MOBOS: A potential European contribution in developing large solar generation suitable for growing power levels up to SPS-systems p0044 879-30752
- [NASA 79-0095] p0049 879-34758
- New energy conversion techniques in space, applicable to propulsion --- powering of aircraft with laser energy from SPS [NASA SPSR 79-1330] p0017 879-40040
- European technology applicable to Solar Power Satellite Systems /SPS/ [NAS SPSR 79-174] p0019 879-51335
- Space-based solar power conversion and delivery systems study, Volume 1: Executive summary [NASA-CR-150294] p0040 879-22617
- Space-based solar power conversion and delivery systems study, Volume 2: Engineering analysis [NASA-CR-150295] p0040 879-22618
- Space-based solar power conversion and delivery systems study, Volume 4: Energy conversion systems studies [NASA-CR-150297] p0040 879-22620
- Satellite Power System (SPS) concept definition study exhibit C, Volume 1: Experimental verification definition [NASA-CR-161294] p0041 879-22632
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 1: Special emphasis studies [NASA-CR-161295] p0041 879-22633
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 1: In-depth element investigation [NASA-CR-161296] p0041 879-22634
- Systems definition space-based power conversion systems --- for satellite power transmission to earth [NASA-CR-150268] p0041 879-23403
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 2, part 1: System engineering [NASA-CR-161299] p0041 879-23405
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 2, part 2: System engineering, cost and programming [NASA-CR-161220] p0042 879-23406
- Satellite Power System (SPS) concept definition study, exhibit C, Volume 2, part 2: System engineering, cost and programming, appendices [NASA-CR-161221] p0042 879-23407
- Satellite Power System (SPS) resource requirements (critical materials, energy and land) [NASA-CR-150600] p0042 879-23412
- Potential of laser for SPS power transmission [NASA-CR-157432] p0042 879-23496
- Satellite Power System (SPS) mapping of exclusion areas for antenna sites [NASA-CR-157435] p0042 879-23499
- Satellite Power System (SPS) military implications [NASA-CR-157436] p0042 879-23500
- Satellite Power System (SPS) financial management scenario [NASA-CR-157438] p0043 879-23502
- Solar Power Satellite Research, Development, and Demonstration Program Act of 1978 [GPO-35-504] p0044 879-30726
- Satellite Power System (SPS) resource requirements (critical materials, energy and land) [NASA-CR-150600] p0042 879-23412
- The NASA Lewis Research Center program in space solar cell research and technology --- efficient silicon solar cell development program p0045 879-32661
- Solar photovoltaic research and development program of the Air Force Aero Propulsion Laboratory --- silicon solar cell applicable to satellite power systems p0045 879-32662
- SATELLITE SOLAR POWER STATIONS**
- An evolutionary solar power satellite program [NAS SPSR 79-153] p0037 879-23265
- A development strategy for the solar power satellite [NAS SPSR 79-154] p0035 879-23266
- Status of the SPS concept development and evaluation program --- Solar Power Satellite p0035 879-33939
- Solar Power Satellite system definition p0035 879-33920
- A review of some critical aspects of satellite power systems p0035 879-33921
- European aspects of Solar Satellite Power systems p0035 879-33923
- SATELLITE SOLAR ENERGY CONVERSION**
- Solar thermoelectric power generation for Mercury orbiter missions





- Environmental factors of power satellites  
[SAMSO-79-79-66] p0039 A79-51487
- Solar power satellite  
[GPO-45-957] p0043 A79-29212
- Satellite Power System (SPS) resource requirements  
(critical materials, energy, and land)  
[NASA-CR-162210] p0044 A79-31251
- SOLAR POWER SOURCES**
- SOLAR CENTRALES**
- SOLAR PROPULSION**
- NT SOLAR ELECTRIC PROPULSION**
- SOLAR REFLECTORS**
- SOLARIS - A new hope for solar energy  
p0047 A79-31952
- System definition space-based power conversion  
systems --- for satellite power transmission to  
earth  
[NASA-CR-150248] p0041 A79-21481
- SOLAR SAILS**
- High performance solar sails and related  
reflecting devices  
[AIAA PAPER 79-1418] p0030 A79-34847
- Attitude control by solar sailing - A promising  
experiment with OTS-2  
p0014 A79-36199
- The inclination change for solar sails and low  
earth orbit  
[AAS PAPER 79-104] p0030 A79-47294
- Assessment of the errors of an analytical method  
of calculating the geocentric trajectories of a  
solar sail  
p0018 A79-53063
- Superlight rotating reflectors in space  
[IAP PAPER 79-112] p0038 A79-53301
- SOLID ROTATION**
- SOLID ROTATING POLYMER**
- SOLID STATE DEVICES**
- NT PHOTOVOLTAIC CELLS**
- NT SEMICONDUCTOR DEVICES**
- SORTIR CAR**
- S SORTIR CAR**
- S SORTIR CAR**
- S SORTIR CAR**
- SPACE BASE COMMAND CENTER**
- A space-based orbital transfer vehicle - Bridge to  
the future  
[AIAA 79-0865] p0047 A79-34305
- SPACE BASES**
- Design and operations technologies - Integrating  
the pieces --- for future space systems design  
[AIAA 79-0856] p0001 A79-34702
- Preliminary design for a space based orbital  
transfer vehicle  
[AIAA 79-0897] p0048 A79-34728
- Global services systems - Space communication  
[AIAA 79-0946] p0408 A79-34761
- System definition space based power conversion  
systems: Executive summary  
[NASA-CR-150209] p0040 A79-22616
- Space construction base control system  
[NASA-CR-161288] p0018 A79-29215
- SPACE CAPSULES**
- NT HYDROGEN SPACECRAFT**
- SPACE COMMUNICATION**
- NT SPACECRAFT COMMUNICATION**
- Space-based radio telescope and an orbiting  
deep-space relay station  
[AIAA 79-0947] p0001 A79-34742
- NASA technology for large space antennas  
p0002 A79-52676
- SPACE ENVIRONMENT**
- S ATROSPACE ENVIRONMENTS**
- SPACE ENVIRONMENT SIMULATION**
- Large space system - Charged particle environment  
interaction technology --- effects on high  
voltage solar array performance  
[AIAA 79-0913] p0148 A79-34775
- Space radiation effects on spacecraft materials  
p0024 A79-43106
- SPACE EXPECTABLE STRUCTURES**
- Freestable platform for science and applications  
payloads circa 1985  
[AIAA 79-0931] p0009 A79-34749
- Deployable antenna technology development for the  
Large Space Systems Technology program  
[AIAA 79-0932] p0009 A79-34750
- Post-fabrication contour adjustment for precision  
parabolic reflectors --- for outer space use  
[AIAA 79-0933] p0009 A79-34751
- A self pulsed laser ranging system under  
development at 'JPL' --- for onboard measurement  
of large space deployable reflector surface  
distortions  
[AIAA 79-0934] p0013 A79-34752
- Maypole /Roop/Column/ deployable reflector concept  
development for 30 to 100 meter antenna  
[AIAA 79-0935] p0009 A79-34753
- Surface accuracy measurement system deployable  
reflector antennas  
[AIAA 79-0937] p0013 A79-34755
- An approach toward the design of large diameter  
offset-fed antennas --- wrap-rib space antennas  
[AIAA 79-0938] p0010 A79-34756
- Large space system automated assembly technique  
[AIAA 79-0939] p0027 A79-34757
- High performance solar sails and related  
reflecting devices  
[AIAA PAPER 79-1418] p0030 A79-34847
- Space structure - A key to new opportunities ---  
deployable antenna and construction/servicing  
system  
[AAS PAPER 79-056] p0001 A79-36149
- Thermal control of a spacecraft-deployable lattice  
booms  
[AIAA PAPER 79-1047] p0007 A79-34831
- A Microwave Radiometer Spacecraft, some control  
requirements and concepts  
[AIAA 79-1777] p0002 A79-45423
- Construction of large space structures  
[IAP PAPER 79-106] p0010 A79-53248
- Dynamic qualification of large space structures by  
means of modal coupling techniques  
[IAP PAPER 79-107] p0008 A79-53299
- A technology base for near-term space platforms  
[IAP PAPER 79-110] p0032 A79-53300
- Superlight rotating reflectors in space  
[IAP PAPER 79-112] p0038 A79-53301
- Satellite solar power station designs with  
concentrators and radiating control  
[IAP PAPER 79-116] p0039 A79-53316
- A space power station without movable parts  
[IAP PAPER 79-177] p0039 A79-53317
- Orbital demonstration - The prelude to large  
operational structures in space  
[IAP PAPER 79-207] p0002 A79-53357
- New space initiatives through large generic  
structures  
[IAP PAPER 79-208] p0002 A79-53358
- Use of a large space structure as an orbital depot  
for hazardous wastes  
[IAP PAPER 79-209] p0039 A79-53359
- Lightweight deployable microwave satellite  
antennae - Need, concepts and related technology  
problems  
[IAP PAPER 79-211] p0010 A79-53361
- Multi-cell satellite for the communications of  
year 2000  
[IAP PAPER 79-301] p0003 A79-53405
- Automatic in-orbit assembly of large space  
structures  
p0028 A79-22562
- Development of a beam builder for automatic  
fabrication of large composite space structures  
p0011 A79-12563
- The dynamics and control of large flexible space  
structures, 2. Part A: Shape and orientation  
control using point actuators  
[NASA-CR-158684] p0016 A79-25122
- Space Construction Automated Fabrication  
Experiment Definition Study (SCAFEDS), part 3.  
Volume 2: Study results  
[NASA-CR-160288] p0011 A79-29201
- Space construction system analysis. Part 1:  
Executive summary  
[NASA-CR-160295] p0004 A79-30266
- Space construction system analysis. Part 2:  
Executive summary. Special emphasis studies  
[NASA-CR-160296] p0004 A79-30266
- SPACE EXPLORATION**
- Technical challenges of large space system in the  
21st century  
[AAS 79-195] p0001 A79-34866
- SPACE FLIGHT**
- NT HANDED SPACE FLIGHT**
- SPACE INDUSTRIALIZATION**
- Technical challenges of large space system in the  
21st century



- [AAS 78-195] p0001 879-34868  
Space to benefit mankind - 1980 to 2000  
[IAF PAPER 79-206] p0049 879-53356
- SPACE MAINTENANCE**  
Satellite power system: Concept development and evaluation program, reference system report  
[DOE/PB-0023] p0139 879-21538
- SPACE MANUFACTURING**  
Large space system automated assembly technique  
[AIAA 79-0939] p0027 879-11757  
High performance solar sails and related reflecting devices  
[AIAA PAPER 79-1438] p0030 879-34847  
Construction in space - Toward a fresh definition of the man/machine relation  
p0027 879-34885  
Space structure - A key to new opportunities --- deployable antenna and construction/servicing system  
[AAS PAPER 79-055] p0001 879-36549  
Solar power satellite - Putting it together --- fabrication, composite materials, and building site considerations  
p0038 879-40399  
Construction of large space structures  
[IAF PAPER 79-106] p0010 879-53298  
Cost comparisons for the use of nonterrestrial materials in space manufacturing of large structures  
[IAF PAPER 79-115] p0038 879-53302  
Space fabrication demonstration system, technical volume  
[NASA-CR-161286] p0011 879-29213  
Space fabrication demonstration system: Executive summary --- for large space structures  
[NASA-CR-161287] p0011 879-29214  
Space construction systems analysis study. Task 3: Construction system shuttle integration  
[NASA-CR-160796] p0050 879-30267  
Space construction data base  
[NASA-CR-160297] p0004 879-30268
- SPACE MISSIONS**  
Materials evaluation for use in long-duration space missions  
p0018 879-41337  
Some activities and vehicle concepts envisioned for future earth orbital missions  
p0003 879-22124  
Pointing and control system enabling technology for future automated space missions  
[NASA-CR-158511] p0016 879-22177  
Large space system: Charged particle environment interaction technology  
[NASA-78-79154] p0049 879-22188  
Primary electric propulsion for future space missions  
[NASA-78-79181] p0030 879-22190  
Concept definition for an extended duration orbiter RC155  
[NASA-CR-160164] p0045 879-13444
- SPACE POWER REACTORS**  
Results from Symposium on Future Critical Power Systems Technology Requirements  
p0038 879-41891
- SPACE PROGRAMS**  
**NT VORSTADT SPACE PROGRAMS**  
The future United States space program: Proceedings of the Twenty-fifth Anniversary Conference, Houston, Tex., October 30-November 2, 1978, Parts 1 & 2  
p0046 879-34843
- SPACE RADIATORS**  
N SPACECRAFT RADIATORS
- SPACE RENDEZVOUS**  
**NT HABIT ORBITAL RENDEZVOUS**  
**SPACE SHUTTLE BOOSTERS**  
**NT REMOVED/RETRIEVING ORBIT TO ORBIT SHUTTLE**
- SPACE SHUTTLE ORBITAL FLIGHT TESTS**  
N SPACE TRANSDUCTION SYSTEM FLIGHTS
- SPACE SHUTTLE ORBITAL FLIGHTS**  
N SPACE TRANSPORTATION SYSTEM FLIGHTS
- SPACE SHUTTLE ORBITERS**  
Orbit transfer operations for the Space Shuttle era  
[IAF PAPER 79-29] p0045 879-53254  
Orbit transfer needs of the late 1980s and the 1990s  
[IAF PAPER 79-30] p0045 879-53256  
Concept definition for an extended duration orbiter RC155  
[NASA-CR-160164] p0045 879-23444
- Space construction systems analysis study. Task 3: Construction system shuttle integration  
[NASA-CR-160296] p0050 879-30267
- SPACE SHUTTLE PAYLOADS**  
**NT SPACEBORNE EXPERIMENTS**  
**NT SPACECLAP**  
Deployable multi-payload platform  
[AIAA 79-0928] p0009 879-34768  
Retractable platform for science and applications payloads circa 1985  
[AIAA 79-0931] p0009 879-34769  
On-orbit assembly of large Space Structures /LSS/ using an autonomous rendezvous and docking  
[AAS PAPER 79-100] p0027 879-47201  
The inclination change for solar sails and low earth orbit  
[AAS PAPER 79-106] p0030 879-47204  
Construction of large space structures  
[IAF PAPER 79-106] p0010 879-53298  
New space initiatives through large generic structures  
[IAF PAPER 79-206] p0002 879-53358
- SPACE SHUTTLES**  
Orbit transfer vehicle propulsion for transfer of Shuttle-deployed large spacecraft to geosynchronous orbit  
[AIAA 79-0880] p0029 879-34716  
Space manipulators - Present capability and future potential --- space shuttle remote handling system  
[AIAA 79-0401] p0027 879-34711  
Planning Space Shuttle's maiden voyage  
p0048 879-44248  
Autonomous mechanical assembly on the space shuttle: An overview  
[NASA-CR-158818] p0028 879-28281
- SPACE STATIONS**  
**NT LONG DURATION EXPOSURE FACILITY**  
**NT ORBITAL SPACE STATION**  
**NT ORBITAL WORKSHOPS**  
**NT ORBITAL 3**  
**NT SPACE BASE COMMAND CENTER**  
Orbital antenna fair power system challenges  
p0002 879-51892  
Space station thermal control surfaces --- space radiators  
[NASA-CR-161217] p0008 879-22178  
A study on solar arrays for programmes leading from the extension of Spacelab towards space platforms  
p0004 879-30748  
Platforms in space: Evolutionary trends  
p0001 879-30879
- SPACE SYSTEMS ENGINEERING**  
N APPROXIMATE ENGINEERING
- SPACE TRANSPORTATION**  
**NT SPACE TRANSPORTATION SYSTEM**  
Planning Space Shuttle's maiden voyage  
p0048 879-44248
- SPACE TRANSPORTATION SYSTEM**  
**NT SPACE SHUTTLE ORBITERS**  
**NT SPACE SHUTTLES**  
NASA technology for large space antennas  
p0002 879-52638  
Magnetospheric and ionospheric impact of large-scale space transportation with ion engines  
[AD-A065492] p0013 879-23138  
Satellite Power System (SPS) concept definition study, exhibit 1. Volume 4: Transportation analysis  
[NASA-CR-161272] p0042 879-21898  
Graphite/Polyimide Composites --- conference on Composites for Advanced Space Transportation Systems  
[NASA-CR-2079] p0025 879-30297  
NASA authorization, 1980, volume 1, part 4  
[GPO-44-423] p0050 879-31085
- SPACE TRANSPORTATION SYSTEM FLIGHTS**  
Mission specification for three generic mission classes  
[NASA-CR-150644] p0004 879-21126
- SPACE VEHICLE CONTROL**  
N SPACECRAFT CONTROL
- SPACEBORNE ASTROPHOT**  
Advanced teleoperators --- remote manipulation system  
p0027 879-34882
- SPACEBORNE EXPERIMENTS**  
LDEF transverse flat plate heat pipe experiment /S102/ --- Long Duration Exposure Facility



- [AIAA PAPER 79-1077] p0033 A79-38053  
**SPACEBORNE TELESCOPES**  
 WT LARGE SPACE TELESCOPE  
 Space-based radio telescopes and an orbiting  
 deep-space relay station  
 [AIAA 79-0947] p0001 A79-34762  
 The possibilities of SETI from space p0002 A79-50459  
 The dynamics and optimal control of spinning  
 spacecraft with movable telescoping appendages p0019 A79-29222
- SPACECRAFT ANTENNAS**  
 A technology program for large area space systems  
 [AIAA 79-0921] p0001 A79-34762  
 Electrostatically formed antennas ---  
 Electrostatically Controlled Membrane Mirror for  
 space applications  
 [AIAA 79-0922] p0013 A79-34763  
 Deployable antenna technology development for the  
 Large Space Systems Technology program  
 [AIAA 79-0932] p0009 A79-34750  
 Post-fabrication contour adjustment for precision  
 parabolic reflectors --- for outer space use  
 [AIAA 79-0933] p0009 A79-34751  
 A self pulsed laser ranging system under  
 development at 'JPL' --- for onboard measurement  
 of large space deployable reflector surface  
 distortions  
 [AIAA 79-0934] p0013 A79-34752  
 NASA technology for large space antennas p0002 A79-52679
- SPACECRAFT CHARGING**  
 Effects of electron irradiation on large  
 insulating surfaces used for European  
 Communications Satellites p0023 A79-36190  
 Spacecraft Charging Technology, 1978  
 [NASA-CP-2071] p0050 A79-24011  
 The calculation of spacecraft potential:  
 Comparison between theory and observation p0050 A79-24019  
 Environmental interaction implications for large  
 space systems p0008 A79-24027  
 Space environmental effects and the solar power  
 satellite p0061 A79-24029  
 Effects of electron irradiation on large  
 insulating surfaces used for European  
 Communications Satellites p0025 A79-24036  
 A confined spacecraft charging and pulsed X-ray  
 simulation facility p0050 A79-24034
- SPACECRAFT COMMUNICATION**  
 Orbital antenna farm power systems challenges  
 p0002 A79-51892  
 The critical satellite technical issues of future  
 pervasive broadband low-cost communication  
 networks  
 [IAF PAPER 79-302] p0001 A79-53406  
 Trends in the design of future communications  
 satellite systems  
 [IAF PAPER 79-307] p0001 A79-53409  
 Space telecommunications at present and in future  
 [IAF PAPER 79-113L-04] p0049 A79-53454
- SPACECRAFT COMPONENTS**  
 WT SERVICE MODULES  
 WT SPACECRAFT MODULES  
 Development of a novel, thermally conducting  
 joint for application to deployable radiators p0012 A79-31314
- SPACECRAFT CONFIGURATIONS**  
 A Microwave Radiometer Spacecraft, some control  
 requirements and concepts  
 [AIAA 79-1777] p0002 A79-45423
- SPACECRAFT CONSTRUCTION MATERIALS**  
 Moisture effects on spacecraft structures  
 p0023 A79-43302  
 Space radiation effects on composite matrix  
 materials - Analytical approaches p0023 A79-43305  
 Space radiation effects on spacecraft materials  
 p0024 A79-43306  
 Materials evaluation for use in long-duration  
 space missions p0024 A79-43307  
 Materials degradation in space environments  
 [AIAA PAPER 79-1500] p0021 A79-46700
- Solar power satellite - Putting it together ---  
 fabrication, composite materials, and building  
 site considerations p0038 A79-50399  
 Cost comparisons for the use of nonterrestrial  
 materials in space manufacturing of large  
 structures  
 [IAF PAPER 79-115] p0038 A79-51302  
 Design fabrication and test of graphite/polyimide  
 composite joints and attachments for advanced  
 aerospace vehicles  
 [NASA-CN-159080] p0011 A79-24066
- SPACECRAFT CONTROL**  
 WT SATELLITE ATTITUDE CONTROL  
 WT SATELLITE CONTROL  
 The dual-momentum control device for large space  
 systems  
 [AIAA 79-0923] p0013 A79-34764  
 Stability and control of future spacecraft systems  
 [AIAA 79-0864] p0014 A79-34766  
 Attitude control requirements for future space  
 systems  
 [AIAA 79-0951] p0014 A79-34767  
 Observability measures and performance sensitivity  
 in the model reduction problem --- applied to  
 flexible spacecraft attitude control p0010 A79-37287  
 The dual momentum control device for large space  
 systems - An example of distributed system  
 adaptive control p0014 A79-41106  
 Guidance and control 1979; Proceedings of the  
 Annual Rocky Mountain Conference, Keystone,  
 Colo., February 24-26, 1979 p0035 A79-44413  
 Guidance and Control Conference, Boulder, Colo.,  
 August 6-8, 1979, Collection of Technical Papers  
 p0035 A79-45351  
 Control of large flexible space structures using  
 pole placement design techniques  
 [AIAA 79-1738] p0015 A79-45380  
 Attitude control of agile flexible spacecraft  
 [AIAA 79-1739] p0015 A79-45381  
 Active control of certain flexible systems using  
 distributed and boundary control --- for large  
 space structures  
 [AIAA 79-1778] p0016 A79-45405  
 An adaptive model control of large flexible  
 spacecraft  
 [AIAA 79-1779] p0016 A79-45406  
 Stability of distributed control for large  
 flexible structures using positivity concepts  
 [AIAA 79-1780] p0016 A79-45407  
 A learning control system extension to the model  
 control of large flexible rotating spacecraft  
 [AIAA 79-1781] p0016 A79-45408  
 Dynamics and control of large space structures -  
 An overview p0017 A79-49832  
 Flexible spacecraft control by model error  
 sensitivity suppression p0017 A79-49833  
 Direct output feedback control of large space  
 structures p0017 A79-49834  
 On cost-sensitivity controller design methods for  
 uncertain dynamic systems p0017 A79-49835  
 Distributed control of two typical flexible  
 structures  
 [IAF PAPER 79-212] p0018 A79-51362  
 Stability of  
 proportional-plus-derivative-plus-integral  
 control of flexible spacecraft p0018 A79-51365
- SPACECRAFT DESIGN**  
 WT SATELLITE DESIGN  
 Conference on Advanced Technology for Future Space  
 Systems, Hampton, Va., May 8-10, 1979, Technical  
 Papers p0047 A79-34701  
 Design and operations technologies - Integrating  
 the pieces --- for future space systems design  
 [AIAA 79-0856] p0021 A79-34702  
 Preliminary design for a space based orbital  
 transfer vehicle  
 [AIAA 79-0897] p0048 A79-34728  
 Planetary mission requirements, technology and  
 design considerations for a solar electric

# SPACECRAFT DOCKING

# SUBJECT INDEX

propulsion stage  
[AIAA 79-0908] p0029 A79-34735  
An economic analysis of a commercial approach to  
the design and fabrication of a space power system  
[AIAA 79-0914] p0036 A79-34737  
Deployable multi-payload platform  
[AIAA 79-0528] p0009 A79-34748  
Communication architecture for large geostationary  
platforms  
[IAF PAPER 79-100] p0011 A79-34804  
Some activities and vehicle concepts envisioned  
for future earth orbital missions p0003 A79-22125

## SPACECRAFT DOCKING

Long interface docking for large space structure  
assembly  
[AIAA 79-0954] p0014 A79-34765  
On-orbit assembly of Large Space Structures /LSS/  
using an autonomous rendezvous and docking  
[AAS PAPER 79-100] p0027 A79-47201  
Relative attitude of large space structures using  
radar measurements  
[AAS PAPER 79-155] p0016 A79-47234

## SPACECRAFT ELECTRONIC EQUIPMENT

Effects of electron irradiation on large  
insulating surfaces used for European  
Communications Satellites p0023 A79-34190

## SPACECRAFT ENVIRONMENTS

Spacecraft Charging Technology, 1978  
[NASA-CP-2071] p0050 A79-24001

## SPACECRAFT GUIDANCE

Guidance and control 1979; Proceedings of the  
Annual Rocky Mountain Conference, Keystone,  
Colo., February 24-26, 1979 p0015 A79-44413  
Guidance and Control Conference, Boulder, Colo.,  
August 6-8, 1979, Collection of Technical Papers p0015 A79-45351

## SPACECRAFT INSTRUMENTS

The dynamics and optimal control of spinning  
spacecraft with movable telescoping appendages p0019 A79-29222

## SPACECRAFT LAUNCHING

First steps to the Solar Power Satellite p0034 A79-32721

## SPACECRAFT MANEUVERS

ON-ORBIT MANEUVERS  
On-orbit assembly of Large Space Structures /LSS/  
using an autonomous rendezvous and docking  
[AAS PAPER 79-100] p0027 A79-47201  
Large angle maneuver strategies for flexible  
spacecraft  
[AAS PAPER 79-156] p0016 A79-47235

## SPACECRAFT MODULES

Orbit transfer operations for the Space Shuttle era  
[IAF PAPER 79-29] p0049 A79-53245

## SPACECRAFT MOTION

Modal truncation for flexible spacecraft  
[AIAA PAPER 79-1765] p0007 A79-92555

## SPACECRAFT ORBITAL ASSEMBLY

### U ORBITAL ASSEMBLY

### SPACECRAFT ORBITS

#### NT GEOSTATIONARY ORBITS

#### NT SATELLITE ORBITS

#### NT TRANSFER ORBITS

The inclination change for solar sails and low  
earth orbit  
[AAS PAPER 79-104] p0030 A79-47204

## SPACECRAFT POWER SUPPLIES

An economic analysis of a commercial approach to  
the design and fabrication of a space power system  
[AIAA 79-0914] p0036 A79-34737  
Solar thermoelectric power generation for Mercury  
orbiter missions  
[AIAA 79-0915] p0029 A79-34738  
Synchronous orbit power technology needs  
[AIAA 79-0916] p0048 A79-34739  
Large space system - Charged particle environment  
interaction technology --- effects on high  
voltage solar array performance  
[AIAA 79-0913] p0048 A79-34735  
Results from Symposium on Future Orbital power  
systems technology requirements  
[NASA-TN-79125] p0004 A79-22191  
An economic analysis of a commercial approach to  
the design and fabrication of a space power system  
[NASA-TN-79153] p0048 A79-22193

Photovoltaic generators in space --- conference,  
ESTEC, Netherlands, Sep. 1978  
[SP-140] p0048 A79-30730  
A study on solar arrays for progress leading  
from the extension of Spacelab towards space  
platform p0004 A79-30748  
Canadian development of large deployable solar  
arrays for communications spacecraft p0050 A79-30754  
The JPL space photovoltaic program --- energy  
efficient and silicon solar cells for space  
applications p0045 A79-32643

## SPACECRAFT PROPULSION

### NT ION PROPULSION

### NT SOLAR ELECTRIC PROPULSION

Conference on Advanced Technology for Future Space  
Systems, Hampton, Va., May 8-10, 1979, Technical  
Papers p0047 A79-34701

Space propulsion technology overview  
[AIAA 79-0860] p0029 A79-34704  
Results from Symposium on Future Orbital Power  
Systems Technology Requirements p0038 A79-51891

Payload capacity of Ariane launched geostationary  
satellites using an electric propulsion system  
for orbit raising  
[IAF PAPER 79-32] p0030 A79-53258  
Primary electric propulsion for future space  
missions  
[NASA-TN-79181] p0030 A79-22190

## SPACECRAFT RADIATORS

Space station thermal control surfaces --- space  
radiators  
[NASA-CP-161217] p0008 A79-22178  
Orbital Test Satellite (OTS) thermal design and  
in-orbit performance p0051 A79-31270  
Development of a movable, thermally conducting  
joint for application to deployable radiators p0012 A79-31314

## SPACECRAFT SENSORS

### U SPACECRAFT INSTRUMENTS

### SPACECRAFT STABILITY

Stability bounds for the control of large space  
structures p0014 A79-41699

## SPACECRAFT STRUCTURES

Thermal control of a spacecraft-deployable lattice  
boom  
[AIAA PAPER 79-1047] p0007 A79-38031  
Moisture effects on spacecraft structures p0023 A79-43302  
A family of sensors for the sensing of the  
position and vibration of spacecraft structures  
[AIAA 79-1741] p0015 A79-45363  
Stability of  
proportional-plus-derivative-plus-integral  
control of flexible spacecraft p0018 A79-53945  
Fabrication of structural elements --- using  
graphite/FMB-15 p0025 A79-30304

## SPACELAB

Planning Space Shuttle's maiden voyage p0048 A79-44248

## SPACELAB PAYLOADS

### NT POINTING CONTROL SYSTEMS

### SPATIAL ORIENTATION

#### U ATTITUDE (INCLINATION)

### SPECTRA

#### NT PLASMA SPECTRA

#### SPHERES

Calculated near characteristics of a large  
spherical reflector antenna p0007 A79-37100

## SPIN STABILIZATION

The dynamics and optimal control of spinning  
spacecraft with movable telescoping appendages p0019 A79-29222

## STABILITY

### NT CONTROL STABILITY

### NT DIMENSIONAL STABILITY

### NT SPACECRAFT STABILITY

### NT SYSTEMS STABILITY

### STABILITY TESTS

Stability of distributed control for large

- flexible structures using positivity concepts  
[AIAA 79-1780] p0014 179-45407
- STABILIZATION**  
NT SPIN STABILIZATION  
NT THREE AXIS STABILIZATION
- STATIC STRUCTURES**  
Decoupling control of a loop flexible beam in orbit  
--- state variable feedback control for large  
space system  
[AAS PAPER 79-156] p0016 179-47236
- STATIC ELECTRICITY**  
New flexible substrates with anti-charging layers  
for advanced lightweight solar arrays  
p0025 179-10717
- STATIC STABILITY**  
NT DIMENSIONAL STABILITY
- STATICS**  
NT ELECTROSTATICS
- STATIONS**  
NT GROUND STATIONS  
NT ORBITAL SPACE STATIONS  
NT ORBITAL WORKSHOPS  
NT SPACE BASE COMMAND CENTER  
NT SPACE STATIONS
- STEADY STATE**  
Optimal local control of flexible structures ---  
for space structures  
[AIAA 79-1740] p0015 179-45182
- STEEL STRUCTURES**  
The dimensioning of complex steel members in the  
range of endurance strength and fatigue life  
p0047 179-24020
- STERNALLY ANTENNAS**  
Calculated upon characteristic of a large  
spherical reflector antenna  
p0007 179-37100
- STIMULATED EMISSION DEVICES**  
NT CARBON DICHLORIDE LASERS  
NT CONTINUOUS WAVE LASERS  
NT INFRARED LASERS  
NT SEEDING LASERS  
NT PULSED LASERS
- STORMS**  
NT MAGNETIC STORMS
- STRAIN DISTRIBUTION**  
U STRESS CONCENTRATION
- STRENGTH OF MATERIALS**  
U MECHANICAL PROPERTIES
- STRESS ANALYSIS**  
The dimensioning of complex steel members in the  
range of endurance strength and fatigue life  
p0047 179-24020
- STRESS CALCULATIONS**  
U STRESS ANALYSIS
- STRESS CONCENTRATION**  
Load concentration due to missing members in  
planar faces of a large space truss  
[NASA-TP-1522] p0008 179-33500
- STRESS DISTRIBUTION**  
U STRESS CONCENTRATION
- STRESS-STRAIN DISTRIBUTION**  
U STRESS CONCENTRATION
- STRESS-STRAIN RELATIONSHIPS**  
A nonlinear stress-strain law for metallic meshes  
--- for large space antennas  
[AIAA 79-0936] p0023 179-34754
- STRINGS**  
Nonreflective boundary control of a vibrating string  
--- application to electrostatically controlled  
large space membrane mirror antennas  
[AIAA 79-0950] p0013 179-34763
- STRUCTURAL ANALYSIS**  
NT DYNAMIC STRUCTURAL ANALYSIS  
Space construction system analysis. Part 1:  
Executive summary. Special emphasis studies  
[NASA-CN-160298] p0004 179-30269  
Study of high stability structural systems:  
Pre-phase A  
[DT-HSS-5] p0012 179-30504
- STRUCTURAL BEAMS**  
U BEAMS (SUPPORTS)
- STRUCTURAL DESIGN**  
Large Advanced Space System /LASS/ Computer Program  
[AIAA 79-0904] p0007 179-34732  
Control of large flexible space structures using  
pole placement design techniques  
[AIAA 79-1738] p0015 179-45380  
Attitude control of agile flexible spacecraft  
[AIAA 79-1739] p0015 179-45381
- Optimization of triangular laced truss columns  
with tubular compression members for space  
application  
p0030 179-48042
- Solar power satellite - Putting it together ---  
fabrication, composite materials, and building  
site considerations  
p0030 179-50299
- STRUCTURAL DESIGN CRITERIA**  
The dimensioning of complex steel members in the  
range of endurance strength and fatigue life  
p0047 179-24020
- Orbital demonstration - The prelude to large  
operational structures in space  
[IAF PAPER 79-207] p0002 179-53357
- STRUCTURAL DYNAMICS**  
U DYNAMIC STRUCTURAL ANALYSIS
- STRUCTURAL ENGINEERING**  
Space construction data base  
[NASA-CN-160297] p0004 179-30268
- STRUCTURAL MATERIALS**  
U CONSTRUCTION MATERIALS
- STRUCTURAL MEMBERS**  
NT BEAMS (SUPPORTS)  
NT COLUMNS (SUPPORTS)  
NT MEMBRANE STRUCTURES  
NT TRUSSES
- STRUCTURAL VIBRATION**  
Nonreflective boundary control of a vibrating string  
--- application to electrostatically controlled  
large space membrane mirror antennas  
[AIAA 79-0950] p0013 179-34763  
A family of sensors for the sensing of the  
position and vibration of spacecraft structures  
[AIAA 79-1741] p0015 179-45383  
Orthogonal subspace reduction of optimal regulator  
order --- for spacecraft structural vibration  
[AIAA 79-1782] p0015 179-45384  
Active control of certain flexible systems using  
distributed and boundary control --- for large  
space structures  
[AIAA 79-1778] p0016 179-45405  
General dynamics of a large class of flexible  
satellite systems  
[IAF PAPER 79-192] p0008 179-51384
- STS**  
U SPACE TRANSPORTATION SYSTEM
- STRUCTURES**  
Derivation of the equations of motion for complex  
structures by symbolic manipulation  
p0007 179-52781
- SUPERHYBRID MATERIALS**  
NT GRAPHITE-EPOXY COMPOSITE MATERIALS
- SUPPORT SYSTEMS**  
NT LIFE SUPPORT SYSTEMS  
Satellite Power System (SPS) concept definition  
study, exhibit C. Volume V: System/subsystem  
requirements data book  
[NASA-CN-161223] p0042 179-23409
- SURFACE GEOMETRY**  
Surface accuracy measurement system deployable  
reflector antennas  
[AIAA 79-0937] p0013 179-34755
- SWEEP FORWARD WINGS**  
Application of Lagrange Optimization to the drag  
polar utilizing experimental data  
[AIAA PAPER 79-1833] p0034 179-49135
- SWEEP WINGS**  
NT SWEEP FORWARD WINGS
- SYMMETRICAL BODIES**  
NT BODIES OF REVOLUTION  
NT SPHERES
- SYNCHRONOUS SATELLITES**  
A method of controlling orbits of geosynchronous  
satellites with minimum fuel consumption  
p0047 179-30782  
Payload capacity of Ariane launched geostationary  
satellites using an electric propulsion system  
for orbit raising  
[IAF PAPER 79-32] p0030 179-53250  
Large geostationary communications platform  
[IAF PAPER 79-210] p0010 179-51360  
Synchronous orbit power technology needs  
[NASA-TN-80280] p0003 179-22174  
Canadian development of large deployable solar  
arrays for communications spacecraft  
p0050 179-30754  
Platforms in space: Evolutionary trends  
p0005 179-30815

## SYNCON &amp; SATELLITE

## WT ARTIFICIAL SATELLITES

## SYNTHETIC APERTURE RADAR

Study of high stability structural systems:

Pre-phase A

[DT-RSS-5]

p0012 A79-30594

## SYSTEMS ANALYSIS

Satellite Power Systems (SPS) concept definition study, exhibit C. Volume 2, part 1: System engineering

[NASA-CR-161219]

p0041 A79-23485

Satellite Power Systems (SPS) concept definition study, exhibit C. Volume 4: Transportation analysis

[NASA-CR-161222]

p0042 A79-23488

Satellite Power Systems (SPS) concept definition study, exhibit C. Volume 7: System/subsystem requirements data book

[NASA-CR-161223]

p0042 A79-23489

Space construction system analysis. Part 1: Executive summary. Special emphasis studies

[NASA-CR-160298]

p0004 A79-30269

Solar power satellites: The Engineering Challenges

p0044 A79-30750

## SYSTEMS DESIGN

## U SYSTEMS ENGINEERING

## SYSTEMS ENGINEERING

A technology program for large area space systems

[AIAA 79-0921]

p0001 A79-34742

On cost-sensitivity controller design methods for uncertain dynamic systems

p0017 A79-49835

Large space system: Charged particle environment interaction technology

[NASA-TM-79156]

p0049 A79-22189

System definition space-based power conversion systems --- for satellite power transmission to earth

[NASA-CR-150268]

p0041 A79-23481

Satellite Power Systems (SPS) concept definition study, exhibit C. Volume 1: Executive summary

[NASA-CR-161218]

p0041 A79-23484

Satellite Power Systems (SPS) concept definition study, exhibit C. Volume 2, part 1: System engineering

[NASA-CR-161219]

p0041 A79-23485

Satellite Power Systems (SPS) concept definition study, exhibit C. Volume 2, part 2: System engineering, cost and programming

[NASA-CR-161220]

p0042 A79-23486

Satellite Power Systems (SPS) concept definition study, exhibit C. Volume 2, part 2: System engineering, cost and programming, appendix

[NASA-CR-161221]

p0042 A79-23487

Space fabrication demonstration system: Executive summary --- for large space structures

[NASA-CR-161287]

p0011 A79-29214

Space construction system analysis study. Task 3: Construction system shuttle integration

[NASA-CR-160296]

p0010 A79-30267

Space construction data base

[NASA-CR-160297]

p0004 A79-30268

Solar power satellites: The Engineering Challenges

p0044 A79-30750

Interface problem on an SPS solar array blanket

p0044 A79-30751

MOSGER: A potential European contribution in developing large solar generators suitable for growing power levels up to SPS-system

p0044 A79-30752

## SYSTEMS STABILITY

Stability analysis of a flexible spacecraft with a sampled-data attitude sensor

p0007 A79-34516

Stability and control of future spacecraft systems

[AIAA 79-0864]

p0014 A79-34766

## T

## TECHNOLOGICAL FORECASTING

The Solar Power Satellite concept - towards the future

p0016 A79-31525

Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers

p0047 A79-34701

Space manipulators - Present capability and future potential --- space shuttle remote handling system

p0027 A79-34982

[AIAA 79-0903]

p0027 A79-34733

A technology program for large area space systems

[AIAA 79-0921]

p0001 A79-34742

Vettable platforms for science and applications

payloads circa 1985

[AIAA 79-0931]

p0009 A79-34749

Global services systems - Space communication

[AIAA 79-0946]

p0008 A79-34761

The future United States space program

Proceedings of the Twenty-fifth Anniversary Conference, Houston, Tex., October 30-November 2, 1978. Parts 1 &amp; 2

p0048 A79-34860

Future programs in space --- impact on energy

technology program

[AAS 78-190]

p0048 A79-34865

Technical challenges of large space systems in the 21st century

[AAS 78-195]

p0001 A79-34868

International Conference on Future Energy

Concepts, London, England, January 30-February 1, 1979, Proceedings

p0016 A79-37882

Orbit transfer needs of the late 1980s and the 1990s

[IAP PAPER 79-30]

p0049 A79-51256

Space to benefit mankind - 1980 to 2000

[IAP PAPER 79-206]

p0049 A79-51256

The critical satellite technical issues of future pervasive broadband low-cost communication networks

[IAP PAPER 79-302]

p0001 A79-51406

Synchronous orbit power technology needs

[NASA-TM-80280]

p0001 A79-22174

## TECHNOLOGIES

## WT ENERGY TECHNOLOGY

## TECHNOLOGY ASSESSMENT

Status of the SPS concept development and evaluation program --- Solar Power Satellite

p0015 A79-31919

Design and operations technologies - Integrating the pieces --- for future space system design

[AIAA 79-0958]

p0001 A79-34702

Space propulsion technology overview

[AIAA 79-0868]

p0029 A79-34704

Satellite solar power stations - Current status and prospects

p0016 A79-37884

Trends in the design of future communications satellite system

[IAP PAPER 79-167]

p0001 A79-51409

Space telecommunications at present and in future

[IAP PAPER 79-IISL-04]

p0049 A79-51454

Satellite power systems: Concept development and evaluation program, reference system report

[DOE/ER-0023]

p0019 A79-21538

Space station thermal control surfaces --- space radiators

[NASA-CR-161217]

p0008 A79-22178

Results from Symposium on Future Orbital power system technology requirements

[NASA-TM-79125]

p0004 A79-22191

Study of membrane reflector technology

[NASA-CR-158729]

p0018 A79-27455

Graphite/polyimide state-of-the-art panel discussion

p0025 A79-30328

## TECHNOLOGY TRANSFER

## WT AEROSPACE TECHNOLOGY TRANSFER

## TECHNOLOGY UTILIZATION

NASA technology for large space antennas

p0002 A79-51474

## TELETRONICS

## U REMOTE HANDLING

## TELECOMMUNICATION

## WT BASIC COMMUNICATION

## WT SPACE COMMUNICATION

## WT SPACECRAFT ANTENNAS

## WT SPACECRAFT COMMUNICATION

## WT VIDEO COMMUNICATION

## WT WIDEBAND COMMUNICATION

Global services systems - Space communication

[AIAA 79-0946]

p0008 A79-34761

Space telecommunications at present and in future

[IAP PAPER 79-IISL-04]

p0049 A79-51454

## TELEOPERATORS

Advanced teleoperators --- remote manipulation system

p0027 A79-34982

- Construction in space - Toward a fresh definition of the man/machine relation  
p0027 179-34965
- Teleoperator system for management of satellite deployment and retrieval  
p0027 179-40539
- TELESCOPES**  
 NT ASTRONOMICAL TELESCOPES  
 NT LARGE SPACE TELESCOPE  
 NT RADIO TELESCOPES  
 NT SPACEBORNE TELESCOPES
- TEMPERATURE CONTROL**  
 Thermal control design analysis of an on-orbit assembly spacecraft  
[AIAA 79-0917] p0007 179-34740  
 Thermal control of a spacecraft-deployable lattice boom  
[AIAA PAPER 79-1047] p0007 179-39031  
 Externally pumped baseline cycle thermal transport devices  
[AIAA PAPER 79-1091] p0048 179-38040  
 Space station thermal control surfaces --- space radiators  
[NASA-CR-161217] p0008 179-22178  
 Orbital Test Satellite (OTS) thermal design and in-orbit performance  
p0051 179-31270  
 Orbital assessment of OTS thermal performance  
p0051 179-31271  
 The OTS hydrazine reaction control system thermal conditioning technique  
p0051 179-31308
- TEMPERATURE EFFECTS**  
 Materials degradation in space environments  
[AIAA PAPER 79-1508] p0025 179-46700
- TENSILE PROPERTIES**  
 Space radiation effects on spacecraft materials  
p0024 179-43306
- TESTS**  
 NT SPACE TRANSPORTATION SYSTEM FLIGHTS
- THERMAL CONDUCTIVITY**  
 Development of a movable, thermally conducting joint for application to deployable radiators  
p0012 179-31316
- THERMAL CONTROL COATINGS**  
 Space station thermal control surfaces --- space radiators  
[NASA-CR-161217] p0008 179-22178  
 Orbital assessment of OTS thermal performance  
p0051 179-31271
- THERMAL EFFECTS**  
 U TEMPERATURE EFFECTS
- THERMAL INSULATION**  
 Effects of electron irradiation on large insulating surfaces used for European Communications Satellites  
p0023 179-34190  
 Orbital assessment of OTS thermal performance  
p0051 179-31271
- THERMAL FLASHES**  
 Plasma particle trajectories around spacecraft propelled by ion thrusters  
p0031 179-24029
- THERMAL PROTECTION**  
 Orbital Test Satellite (OTS) thermal design and in-orbit performance  
p0051 179-31270
- THERMIONIC CONVERSION SYSTEMS**  
 U THERMIONIC POWER GENERATION
- THERMIONIC POWER GENERATION**  
 Systems definition space-based power conversion systems --- for satellite power transmission to earth  
[NASA-CR-150248] p0041 179-23483
- THERMIONIC REACTORS**  
 U ION ENGINES
- THERMODYNAMIC CYCLES**  
 NT RANKINE CYCLE
- THERMODYNAMIC PROPERTIES**  
 NT THERMAL CONDUCTIVITY  
 NT THERMOPHYSICAL PROPERTIES
- THERMOELECTRIC CONVERSION SYSTEMS**  
 U THERMOELECTRIC POWER GENERATION
- THERMOELECTRIC POWER GENERATION**  
 Solar thermoelectric power generation for Mercury orbiter systems  
[AIAA 79-0915] p0026 179-34738
- THERMOPHYSICAL PROPERTIES**  
 NT THERMAL CONDUCTIVITY
- Space radiation effects on spacecraft materials  
p0024 179-43306
- THERMOTROPISM**  
 U TEMPERATURE EFFECTS
- THREE AXIS STABILIZATION**  
 Distributed control of two typical flexible structures  
[IAF PAPER 79-212] p0018 179-51362
- TILT**  
 U ATTITUDE (INCLINATION)
- TILTING**  
 U ATTITUDE (INCLINATION)
- TIME**  
 Concept definition for an extended duration orbiter ECLES  
[NASA-CR-160164] p0049 179-23166
- TRAJECTORIES**  
 NT PARTICLE TRAJECTORIES
- TRANSFER ORBITS**  
 Preliminary design for a space based orbital transfer vehicle  
[AIAA 79-0897] p0048 179-34728  
 Low-thrust chemical orbit transfer propulsion  
[AIAA PAPER 79-1192] p0030 179-39815  
 Orbit transfer operations for the Space Shuttle era  
[IAF PAPER 79-29] p0049 179-51255  
 Orbit transfer needs of the late 1980s and the 1990s  
[IAF PAPER 79-30] p0049 179-51256  
 Payload capacity of Ariane launched geostationary satellites using an electric propulsion system for orbit raising  
[IAF PAPER 79-32] p0030 179-51258  
 Low-thrust chemical orbit transfer propulsion  
[NASA-TN-79190] p0031 179-25129
- TRANSMISSION**  
 NT ELECTRIC POWER TRANSMISSION  
 NT ELECTROMAGNETIC WAVE TRANSMISSION  
 NT HEAT TRANSFER  
 NT IONOSPHERIC PROPAGATION  
 NT MICROWAVE TRANSMISSION
- TRANSMISSION EFFICIENCY**  
 Space Laser Power System --- for satellite solar power station transmission to earth  
[AIAA PAPER 79-1013] p0036 179-38201  
 Solar power satellites - Microwaves deliver the power  
p0037 179-38374
- TRANSFER PROPERTIES**  
 NT ELECTRICAL RESISTIVITY  
 NT THERMAL CONDUCTIVITY
- TRANSPORTATION**  
 NT AIR TRANSPORTATION  
 NT SPACE TRANSPORTATION  
 NT SPACE TRANSPORTATION SYSTEM
- TRIGGERS**  
 U ACTUATORS
- TRUSSES**  
 Dimensional stability investigation - Graphite/epoxy truss structure  
p0024 179-43330  
 Optimization of triangular laced truss columns with tubular compression members for space application  
p0010 179-46062  
 Load concentration due to missing members in planar faces of a large space truss  
[NASA-TN-1522] p0008 179-13100
- TURBINE ENGINES**  
 NT TURBOFAN ENGINES  
 NT TURBOJET ENGINES
- TURBOJET ENGINES**  
 New energy conversion techniques in space, applicable to propulsion --- powering of aircraft with laser energy from SPS  
[AIAA PAPER 79-1338] p0037 179-40490
- TURBOJET ENGINES**  
 NT TURBOFAN ENGINES
- U**
- UNITED STATES OF AMERICA**  
 The future United States space program;  
 Proceedings of the Twenty-fifth Anniversary Conference, Houston, Tex., October 30-November 2, 1976. Parts 1 & 2  
p0048 179-34860
- UNMANNED SPACECRAFT**  
 Pointing and control system enabling technology for future automated space missions  
[NASA-CR-158513] p0018 179-22177



## UPPER STAGE ROCKET ENGINES

Orbit transfer vehicle propulsion for transfer of  
Shuttle-deployed large spacecraft to  
geosynchronous orbit  
[AIAA 79-0886] p0029 879-34716

GSA (UNITED STATES)  
U UNITED STATES OF AMERICA  
UTILIZATION  
UT LASED APPLICATIONS

## V

V/STOL AIRCRAFT  
VT FLYING PLATFORMS  
VACUUM EFFECTS  
Materials degradation in space environments  
[AIAA PAPER 79-1508] p0025 879-46700

VACUUM TUBE OSCILLATORS  
VT KLYSTRONS  
VACUUM TUBES  
VT KLYSTRONS  
VALANCE  
New highly conducting coordination compounds  
[AD-A064795] p0040 879-22261

VECTION CONTROL  
U DIRECTIONAL CONTROL  
VECTOR SPACES  
VT STATE VECTORS  
VECTORS (MATHEMATICS)  
VT STATE VECTORS  
VERTICAL TAKEOFF AIRCRAFT  
VT FLYING PLATFORMS  
VERY LONG BASE INTERFEROMETRY  
Space-based radio telescopes and an orbiting  
deep-space relay station  
[AIAA 79-0547] p0001 879-14762

VIBRATION  
VT STRUCTURAL VIBRATIONS  
Orthogonal subspace reduction of optimal regulator  
order --- for spacecraft structural vibration  
[AIAA 79-1742] p0015 879-45394

VIBRATION DAMPING  
Active control of certain flexible systems using  
distributed and boundary control --- for large  
space structures  
[AIAA 79-1778] p0016 879-45405

VIBRATION MEASUREMENT  
A family of sensors for the sensing of the  
position and vibration of spacecraft structures  
[AIAA 79-1741] p0015 879-45393

VIBRATION MODE  
Direct velocity feedback control of large space  
structures  
p0013 879-34523

Modal truncation for flexible spacecraft  
[AIAA PAPER 79-1745] p0007 879-52555

VIDEO COMMUNICATION  
Global services systems - Space communication  
[AIAA 79-0546] p0408 879-34761

VIBRI  
U VERY LONG BASE INTERFEROMETRY  
VOLTAGE  
U ELECTRIC POTENTIAL  
VOLTAGE GENERATORS  
VT PHOTOVOLTAIC CELLS

## W

WASTE DISPOSAL  
Use of a large space structure as an orbital depot  
for hazardous wastes  
[IAF PAPER 79-209] p0029 879-53359

WASTES  
VT RADIOACTIVE WASTES  
WATER CONTENT  
U MOISTURE CONTENT  
WAVE PROPAGATION  
VT IONOSPHERIC PROPAGATION  
WEAPONS DEVELOPMENT  
Satellite Power System (SPS) military implications  
[NASA-CR-157436] p0042 879-21500

WEBS (MEMBRANES)  
U MEMBRANES  
WELDED STRUCTURES  
VT STEEL STRUCTURES  
WETNESS  
U MOISTURE CONTENT  
WIDEBAND COMMUNICATION  
The critical satellite technical issues of future

pervasive broadband low-cost communication  
networks  
[IAF PAPER 79-302] p0001 879-53406

WING PLANFORMS  
VT SWEEP FORWARD WINGS  
WINGS  
VT SWEEP FORWARD WINGS  
WRAPAROUND CONTACT SOLAR CELLS  
U SOLAR CELLS

## X

X RAY APPARATUS  
A combined spacecraft charging and pulsed X-ray  
insulation facility  
p0050 879-24054

## Y

YAWMETERS  
U ATTITUDE INDICATORS

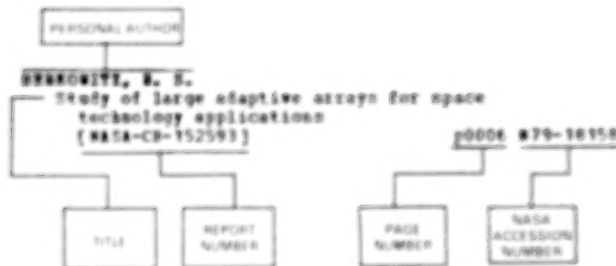


# PERSONAL AUTHOR INDEX

TECHNOLOGY FOR LARGE SPACE SYSTEMS/*A Special Bibliography (Suppl. 2)*

JANUARY 1980

## Typical Personal Author Index Listing



Listings in this index are arranged alphabetically by personal author. The title of the document provides the user with a brief description of the subject matter. The report number helps to indicate the type of document listed (e.g. NASA report, translation, NASA contractor report). The page and accession numbers are located beneath and to the right of the title (e.g. p0006 879-18158). Under any one author's name the accession numbers are arranged in sequence with the TAA accession numbers appearing first.

## A

- ARDEL-SAMMAN, Y. N.**  
Stability of proportional-plus-derivative-plus-integral control of flexible spacecraft  
p0016 879-53945
- AGRAWAL, P. K.**  
Calculated scan characteristics of a large spherical reflector antenna  
p0007 879-37100
- ARNOLD, S.**  
Canadian development of large deployable solar arrays for communications spacecraft  
p0050 879-38754
- ANDERSON, R.**  
A nonlinear stress-strain law for metallic senken  
[ATAA 79-0936]  
p0023 879-34754
- ANDERSON, M. H.**  
A family of sensors for the sensing of the position and vibration of spacecraft structures  
[ATAA 79-1741]  
p0015 879-45303
- ANDRYCZYK, R.**  
Solar power satellite ground stations  
p0037 879-44249
- ARCHER, J. S.**  
Post-fabrication contour adjustment for precision parabolic reflectors  
[ATAA 79-0911]  
p0009 879-34751
- ARMSTRONG, R. E.**  
Satellite applications of metal-matrix composites  
p0024 879-43321

## B

- BACON, J. F.**  
Graphite fiber reinforced glass matrix composites for aerospace applications  
p0023 879-43234
- BAIR, C. M.**  
Potential of laser for SPS power transmission  
[NASA-CR-157432]  
p0042 879-23496
- BALAS, M. J.**  
Satellite Power System (SPS) military implications  
[NASA-CR-157436]  
p0042 879-23500
- BAIRD, P. M.**  
Decoupling control of a long flexible beam in orbit  
[AAS PAPER 79-158]  
p0036 879-47236
- BAIRD, P. M.**  
The dynamics and control of large flexible space structures. J. Part A: Shape and orientation control using point actuators  
[NASA-CR-158604]  
p0010 879-25122
- BAIAS, M. J.**  
Direct velocity feedback control of large space structures  
p0013 879-34523

- BALAS, M. J.**  
Direct output feedback control of large space structures  
p0017 879-49634
- BALLER, M. P.**  
The possibilities of SETI from space  
p0032 879-50459
- BARINGER, R. A.**  
Satellite Power System (SPS) mapping of exclusion areas for rectenna sites  
[NASA-CR-157435]  
p0042 879-23499
- BARON, J.**  
An economic analysis of a commercial approach to the design and fabrication of a space power system  
[ATAA 79-0910]  
p0034 879-34737
- BARON, J. F.**  
An economic analysis of a commercial approach to the design and fabrication of a space power system  
[NASA-TN-79153]  
p0040 879-22193
- BARRETT, A. E.**  
Advanced telescopes  
p0027 879-34582
- BARSHAD, R. J.**  
Control of large space structures using equilibrium enforcing optimal control  
[ATAA 79-0927]  
p0013 879-34747
- BARSHAD, R. J.**  
Stability of distributed control for large flexible structures using positivity concepts  
[ATAA 79-1780]  
p0016 879-45407
- BARSHAD, R. J.**  
A self pulsed laser ranging system under development at 'JPL'  
[ATAA 79-0934]  
p0013 879-34752
- BARSHAD, R. J.**  
Dynamic qualification of large space structures by means of modal coupling techniques  
[IAP PAPER 79-107]  
p0008 879-51299
- BART, V.**  
Feasibility study for a satellite frequency isolated radio communication system  
[NASA-CR-1151-90L-1]  
p0004 879-27176
- BILLMURPHY, M. J.**  
Synchronous orbit power technology needs  
[ATAA 79-0916]  
p0040 879-34739
- BILLMURPHY, M. J.**  
Synchronous orbit power technology needs  
[NASA-TN-80280]  
p0003 879-22174
- BILLMAN, R. W.**  
SOLARIS - A new hope for solar energy  
p0047 879-33992
- BLACKBURN, J. E., JR.**  
Satellite Power System (SPS) mapping of exclusion areas for rectenna sites  
[NASA-CR-157435]  
p0042 879-23499
- BOCK, R. E.**  
Cost comparisons for the use of nonterrestrial materials in space manufacturing of large structures  
[IAP PAPER 79-115]  
p0038 879-53302
- BOBLE, J. G.**  
Development of a beam builder for automatic fabrication of large composite space structures  
p0011 879-22563
- BOGGS, R.**  
Photovoltaic generators in space  
[SP-140]  
p0044 879-30730
- BOIRO, V. A.**  
Anomalous intensity ratios of the resonance to intercombination lines of He-like ions in He- and CO<sub>2</sub>-laser-produced plasma  
p0047 879-24021
- BOND, A. C.**  
The 11th Aerospace Mechanisms Symposium  
[NASA-CR-2001]  
p0040 879-22539

- NOON, F. E.**  
Communication architecture for large geostationary platform  
[IAF PAPER 79-309] p0011 879-53404
- NOON, F. E.**  
Canadian development of large deployable solar arrays for communications spacecraft  
p0050 879-30754
- NOON, F. E., JR.**  
Magnetospheric and ionospheric impact of large-scale space transportation with ion engines  
[AD-8065482] p0011 879-23194
- NOON, J. F.**  
Orbital assessment of CTS thermal performance  
p0011 879-31271
- NOON, S. W.**  
SOLARIS - A new hope for solar energy  
p0047 879-31992
- NOYER, R.**  
A nonlinear stress-strain law for metallic composites  
[AIAA 79-0516] p0021 879-34754
- NOVAKOVICH, R. W., JR.**  
The NASA Lewis Research Center program in space solar cell research and technology  
p0045 879-32641
- NOYER, R. F.**  
Preliminary design for a space based orbital transfer vehicle  
[AIAA 79-0897] p0048 879-34720
- NOYER, R. F.**  
Relative attitude of large space structures using radar measurements  
[AAS PAPER 79-155] p0019 879-47234
- NOYER, J.**  
Distributed control of two typical flexible structures  
[IAF PAPER 79-212] p0019 879-53362
- NOYER, R.**  
Concept definition for an extended duration orbiter vehicle  
[NASA-CR-340164] p0045 879-23666
- NOYER, R. F.**  
New highly conducting coordination compounds  
[AD-8064735] p0040 879-22261
- NOYER, G. L.**  
Space radiation effects on spacecraft materials  
p0024 879-43306
- NOYER, W. C.**  
Solar power satellites - Microwaves deliver the power  
p0017 879-34374
- NOYER, W. C.**  
The technology base for the microwave power transmission system in the US  
p0018 879-51941
- NOYER, C.**  
Solar-pumped lasers for space power transmission  
[AIAA PAPER 79-1015] p0017 879-34202
- NOYER, R. F.**  
A family of sensors for the sensing of the position and vibration of spacecraft structures  
[AIAA 79-1741] p0019 879-45303
- NOYER, W. L.**  
Stabilization of the shape of a deploying surface  
p0017 879-50641
- NOYER, J.**  
Space telecommunications at present and in future  
[IAF PAPER 79-1111-04] p0045 879-53454
- NOYER, J. W., JR.**  
A programmable power processor for a 25-kW power module  
[NASA-TR-74215] p0011 879-26641
- NOYER, J. W., JR.**  
Platform in space: Revolutionary trends  
p0005 879-34879
- NOYER, D. C.**  
Primary electric propulsion for future space missions  
[NASA-TR-79141] p0010 879-22790

C

- CAGLAYAN, A. E.**  
Nonreflective boundary control of a vibration system  
[AIAA 79-0510] p0013 879-34761
- CAGLAYAN, A. E.**  
Active control of certain flexible systems using distributed and boundary control  
[AIAA 79-1778] p0019 879-45405
- CAMPBELL, T. G.**  
Deployable antenna technology development for the

- Large Space Systems Technology program  
[AIAA 79-0932] p0009 879-34754
- CARRING, R.**  
New highly conducting coordination compounds  
[AD-8064735] p0040 879-22261
- CHAPMAN, J. J.**  
Thermal control of a spacecraft-deployable lattice boom  
[AIAA PAPER 79-1047] p0007 879-34031
- CHARTER, J.**  
Solar power satellite ground stations  
p0017 879-44249
- CHENG, S. S.**  
Magnetospheric and ionospheric impact of large-scale space transportation with ion engines  
[AD-8065482] p0011 879-23194
- CHENG, S. S.**  
Environmental factors of power satellites  
[SAMSO-TR-79-66] p0043 879-26213
- CHENG, S. S.**  
Magnetospheric and ionospheric impact of large-scale space transportation with ion engines  
[AD-8065482] p0011 879-23194
- CHENG, S. S.**  
Environmental factors of power satellites  
[SAMSO-TR-79-66] p0043 879-26213
- CHRISTIANSEN, R.**  
Solar-pumped lasers for space power transmission  
[AIAA PAPER 79-1015] p0017 879-34202
- CHRISTIANSEN, R. W.**  
Knowledge intensity ratios of the resonance to intercombination lines of He-like ions in 94- and 102-laser-produced plasma  
p0047 879-24021
- COLLINS, P. G.**  
Satellite solar power stations - Current status and prospects  
p0016 879-37044
- COLSON, W. B.**  
New methods for the conversion of solar energy to D. F. and laser power  
[AIAA PAPER 79-1416] p0016 879-34844
- COOK, S.**  
Space environmental effects and the solar power satellite  
p0043 879-24020
- COPELAND, R. L.**  
Plasma particle trajectories around spacecraft propelled by ion thrusters  
p0011 879-24029
- CORADINTE, P.**  
Orthogonal subspace reduction of optimal regulator order  
[AIAA 79-1742] p0015 879-45304
- CORADINTE, P.**  
Flexible spacecraft control by model error sensitivity suppression  
p0017 879-44911
- CORR, R. J.**  
Planetary mission requirements, technology and design considerations for a solar electric propulsion stage  
[AIAA 79-0908] p0029 879-34735
- COTTER, J. V.**  
Foldable beam  
[NASA-CR-148-12077-1] p0011 879-25425
- CRAWFORD, R. P.**  
Foldable beam  
[NASA-CR-148-12077-1] p0011 879-25425
- CROSWELL, W. F.**  
Calculated scan characteristics of a large spherical reflector antenna  
p0007 879-37100
- CULP, R. B.**  
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p0015 879-44413
- CURLEY, R. C.**  
Graphite/polyimide state-of-the-art panel discussion  
p0025 879-30329
- CHERRY, R. J., JR.**  
Construction of large space structures  
[IAF PAPER 79-106] p0010 879-53249

D

- DARLINGTON, J. B.**  
Attitude control requirements for future space

- systems  
[AIAA 79-0951] p0014 879-36367  
Pointing and control system enabling technology  
for future automated space missions  
[NASA-CR-350513] p0018 879-22177
- DANES, F. J., JR.  
Fabrication of structural elements p0025 879-30306
- DAVIS, M. P.  
Orbit transfer operations for the Space Shuttle era  
[IAP PAPER 79-29] p0049 879-53255
- DAVIS, J. G., JR.  
Graphite/Polysulfide Composites  
[NASA-CR-2679] p0025 879-30297
- DAY, P.  
New highly conducting coordination compounds  
[AD-A066735] p0040 879-22261
- DEYER, R. B.  
Graphite/Polysulfide Composites  
[NASA-CR-2679] p0027 879-30297
- DEYER, R. B.  
Graphite fiber reinforced glass matrix composites  
for aerospace applications p0023 879-47236
- DIERHARDT, M. W.  
Large multibeam space antennas  
[AIAA 79-0942] p0010 879-36756
- DILLY, J.  
Multi-cell satellite for the communications of  
year 2000  
[IAP PAPER 79-301] p0003 879-53405
- DRENNAN, R. E.  
High performance solar sails and related  
reflecting devices  
[AIAA PAPER 79-1456] p0030 879-36847
- DOWN, V. J.  
Construction of large space structures  
[IAP PAPER 79-106] p0010 879-53298

## E

- EDMONDS, M. S.  
Attitude control requirements for future space  
systems  
[AIAA 79-0951] p0014 879-36367
- ELDR, D. G.  
A space-based orbital transfer vehicle - Bridge to  
the future  
[AIAA 79-0865] p0047 879-36705
- ELDR, C. B.  
Design and operations technologies - Integrating  
the pieces  
[AIAA 79-0958] p0001 879-36702
- ELLISON, A. M.  
The application of metal-matrix composites to  
spaceborne parabolic antennas p0026 879-43322
- ELMS, B. V., JR.  
SEP solar array development testing p0036 879-51406
- EDOR, P. R.  
Orbital antenna fare power systems challenges  
p0002 879-51402

## F

- FACK, S. R.  
A combined spacecraft charging and pulsed X-ray  
simulation facility p0050 879-24054
- FANROV, S. II.  
Anomalous intensity ratios of the resonance to  
intercombination lines of Be-like ions in He-  
and CO<sub>2</sub>-laser-produced plasma p0047 879-24021
- FASOLD, B.  
Lightweight deployable microwave satellite  
antennae - Need, concepts and related technology  
problems  
[IAP PAPER 79-211] p0010 879-53361
- FISCHER, W.  
Environmental interaction implications for large  
space systems p0008 879-24027
- FOLDS, P.  
Large multibeam space antennas  
[AIAA 79-0942] p0010 879-36756  
Solar power satellite ground stations  
p0037 879-44200

- FRANKLIN, L. W.  
A review of some critical aspects of satellite  
power systems p0075 879-31921
- FRANKLIN, L. W.  
Deployable antenna technology development for the  
Large Space Systems Technology program  
[AIAA 79-0932] p0009 879-36750  
NASA technology for large space antennas  
p0002 879-52670
- FRANKLIN, J. R.  
New methods for the conversion of solar energy to  
S. V. and laser power  
[AIAA PAPER 79-1456] p0036 879-36846  
Space environmental effects and the solar power  
satellite p0043 879-24026
- FRITZ, R. P.  
Planning Space Shuttle's maiden voyage  
p0048 879-44200
- FULFORD, C. W. G.  
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Conference, Houston, Tex., October 30-November  
2, 1978, Parts 1 & 2 p0048 879-36846

## G

- GANG, S.  
Stability analysis of a flexible spacecraft with a  
sampled-data attitude sensor p0007 879-36736
- GARIBOTTI, J. P.  
Construction of large space structures  
[IAP PAPER 79-106] p0010 879-53298
- GARIBOTTI, R. L.  
The calculation of spacecraft potential:  
Comparison between theory and observation  
p0050 879-24019
- GIEDLER, R. M.  
Large solid deployable reflector  
[AIAA 79-0925] p0009 879-36746
- GILBERT, G. P.  
SOLARIS - A new hope for solar energy  
p0007 879-31992
- GILBERT, P. R. C.  
A study on solar arrays for programmes leading  
from the extension of Spacelab towards space  
platforms p0004 879-30748
- GIOMI, C.  
Space radiation effects on composite matrix  
materials - Analytical approaches p0023 879-43305
- GLASS, P. R.  
First steps to the Solar Power Satellite  
p0036 879-32721  
The development of solar power satellites  
p0036 879-35408  
The solar power satellite concept  
p0037 879-44277
- GOLDEN, R.  
Multi-cell satellite for the communications of  
year 2000  
[IAP PAPER 79-301] p0003 879-53405
- GOSLAND, S.  
Results from Symposium on Future Orbital Power  
System Technology Requirements p0036 879-51091
- GOSLAND, S.  
Results from Symposium on Future Orbital power  
system technology requirements  
[NASA-TN-79125] p0004 879-22191
- GOSLAND, G. L.  
Space to benefit mankind - 1980 to 2000  
[IAP PAPER 79-206] p0049 879-53356
- GOSWAMI, R.  
Distributed control of two typical flexible  
structures  
[IAP PAPER 79-212] p0010 879-53362
- GRAN, J. R.  
Space manipulators - Present capability and future  
potential  
[AIAA 79-0903] p0027 879-36731
- GREENMAN, P.  
Vision solar concentrators and evaluation  
support. Phase 2: Non-imaging concentrators  
for space applications  
[NASA-CR-162279] p0044 879-31766

- GREGORY, D. L.  
A development strategy for the solar power satellite  
[AAS PAPER 79-156] p0071 879-24266
- GRIN, N. V.  
Large space system - Charged particle environment  
interaction technology  
[AAS 79-0913] p0009 879-36775
- GRIN, N. V.  
Large space system: Charged particle environment  
interaction technology  
[NASA-79-79156] p0009 879-22100
- GRINTVITSEVA, L. V.  
Assessment of the errors of an analytical method  
of calculating the geocentric trajectories of a  
solar sail  
p0076 879-53063
- GROSS, R. A.  
Stability bounds for the control of large space  
structures  
p0076 879-61099
- GUASTAFERRI, A.  
A technology program for large area space systems  
[AAS 79-0921] p0001 879-30702
- GUASTAFERRI, A.  
A technology base for near-term space platforms  
[AAS PAPER 79-110] p0002 879-51300
- GUTWINE, T. D.  
Photovoltaic generators in space  
[SP-160] p0004 879-30730

## H

- HAGLES, V.  
Orbital demonstration - The prelude to large  
operational structures in space  
[AAS PAPER 79-207] p0002 879-5377
- HALE, A. L.  
Derivation of the equations of motion for complex  
structures by symbolic manipulation  
p0007 879-52701
- HALL, K. R.  
A learning control system extension to the solar  
control of large flexible rotating spacecraft  
[AAS 79-1701] p0006 879-05400
- HANSEN, R. A.  
Decoupling control of a long flexible beam in orbit  
[AAS PAPER 79-156] p0076 879-67236
- HARR, A. L.  
Indirect adaptive stabilization of a large,  
flexible, spinning spacecraft simulation studies  
p0077 879-50033
- HAWLEY, G.  
Satellite Power System (SPS) concept definition  
study, exhibit C, Volume 3: Special emphasis  
studies  
[NASA-CR-161215] p0001 879-22033
- HAWLEY, G.  
Satellite Power System (SPS) concept definition  
study, exhibit C, Volume 4: In-depth element  
investigation  
[NASA-CR-161216] p0001 879-22030
- HAWLEY, G. M.  
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[AAS PAPER 79-153] p0076 879-24265
- HAWLEY, G. M.  
First steps to the Solar Power Satellite  
p0036 879-32721
- HAWLEY, G. M.  
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study, exhibit C, Volume 1: Executive summary  
[NASA-CR-161218] p0001 879-23046
- HAWLEY, G. M.  
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study, exhibit C, Volume 2, part 1: System  
engineering  
[NASA-CR-161219] p0001 879-23045
- HAWLEY, G. M.  
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study, exhibit C, Volume 2, part 2: System  
engineering, cost and programming  
[NASA-CR-161220] p0002 879-23046
- HAWLEY, G. M.  
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study, exhibit C, Volume 3, part 1: System  
engineering, cost and programming, appendices  
[NASA-CR-161221] p0002 879-23047
- HAWLEY, G. M.  
Satellite Power System (SPS) concept definition  
study, exhibit C, Volume 4: Transportation  
analysis  
[NASA-CR-161222] p0002 879-23048
- HAWLEY, G. M.  
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study, exhibit C, Volume 5: System/subsystem  
requirements data book  
[NASA-CR-161223] p0002 879-23049
- HAWKINS, R. A.  
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devices  
p0004 879-30730

- [AAS PAPER 79-1091] p0006 879-30060
- HASTON, R.  
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satellite systems  
[AAS PAPER 79-107] p0003 879-53009
- HASTON, R.  
Trends in the design of future communications  
satellite systems  
[AAS PAPER 79-107] p0003 879-53009
- HASTON, R. A.  
Orbit transfer needs of the late 1980s and the 1990s  
[AAS PAPER 79-107] p0003 879-53009
- HAWLEY, G. L.  
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passive broadband low-cost communication  
systems  
[AAS PAPER 79-107] p0003 879-53009
- HASTON, R. C.  
Planetary mission requirements, technology and  
design considerations for a solar electric  
propulsion stage  
[AAS 79-0906] p0024 879-36725
- HAWKINS, C. A.  
Increased capabilities of the 30-cm diameter 80  
ton thruster  
[AAS 79-0910] p0030 879-36776
- HEALD, D. A.  
Is a versatile orbit transfer stage feasible  
[AAS 79-0866] p0029 879-36772
- HEIDENRICH, J.  
Study of membrane reflector technology  
[NASA-CR-150729] p0010 879-27655
- HEIDENRICH, J. A.  
Expandable modules for large space structures  
[AAS 79-0924] p0009 879-30705
- HEIDENRICH, J. A.  
Foldable beam  
[NASA-CR-161207-1] p0011 879-25425
- HEIDENRICH, J. A.  
Geometric model and analysis of rod-like large  
space structures  
[NASA-CR-150709] p0006 879-23120
- HEIDENRICH, J. A.  
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antenna - Need, concepts and related technology  
problems  
[AAS PAPER 79-211] p0010 879-51361
- HEIDENRICH, J. A.  
A power transmission concept for a European SPS  
system  
p0030 879-53007
- HEIDENRICH, R. A.  
Energy analysis of the Solar Power Satellite  
p0037 879-48160
- HEPPE, J.  
Moisture effects on spacecraft structures  
p0071 879-61302
- HEIDENRICH, J. A.  
New energy conversion techniques in space,  
applicable to propulsion  
[AAS PAPER 79-110] p0002 879-51300
- HEIDENRICH, J. A.  
Development of a movable, thermal conducting  
joint for application to deployable radiators  
p0017 879-51364
- HO, J. Y. L.  
Attitude control of agile flexible spacecraft  
[AAS 79-1739] p0076 879-67236
- HUFFMAN, S.  
New highly conducting composites compounds  
[AD-806473] p0000 879-761
- HODGSON, R.  
Feasibility study for a satellite frequency  
modulated radio communication system  
[NASA-CR-1511-001-1] p0004 879-23176
- HODGSON, R. B.  
Orbital assessment of OTS thermal performance  
p0051 879-11271
- HODGSON, R. C.  
A family of sensors for the sensing of the  
position and vibration of spacecraft structures  
[AAS 79-1741] p0076 879-67236
- HODGSON, R. A., III  
A technology base for near-term space platforms  
[AAS PAPER 79-110] p0002 879-51300
- HODGSON, R. C.  
Modal truncation for flexible spacecraft  
[AAS PAPER 79-1745] p0007 879-52555
- HODGSON, R. C.  
Stability of  
proportional-plus-derivative-plus-integral

control of flexible spacecraft

p0018 879-53965

## I

IMHOFF, R. A.

Automatic intensity control of the resonance to  
intercombination lines of He-like ions in He-  
and He<sup>+</sup>-laser-produced plasmas

p0067 879-29221

IMHOFF, R. A.

Control of large space structures using  
equilibrium enforcing optimal control

[AIAA 79-0527]

p0011 879-26267

Stability of distributed control for large  
flexible structures using positivity concepts

[AIAA 79-1780]

p0156 879-65607

## J

JACKSON, R. L.

Stability of distributed control for large  
flexible structures using positivity concepts

[AIAA 79-1780]

p0156 879-65607

JACKSON, R. L.

Automatic in-orbit assembly of large space  
structures

p0028 879-22162

JACQUES, J. A.

Space station thermal control surfaces

[NASA-CR-161277]

p0008 879-22178

JACKSON, R. L.

Deployable multi-payload platform

[AIAA 79-0528]

p0009 879-26266

JACKSON, R. L.

The dual moment control device for large space  
systems

[AIAA 79-0573]

p0011 879-26266

The dual moment control device for large space  
systems - An example of distributed system  
adaptive control

p0014 879-61106

On adaptive modal control of large flexible  
spacecraft

[AIAA 79-1779]

p0096 879-61106

Indirect adaptive stabilization of a large,  
flexible, spinning spacecraft simulation studies

p0017 879-53033

JACKSON, R. L.

Solar power satellite - Putting it together

p0038 879-50399

New space initiatives through large generic  
structures

[IAF PAPERS 79-200]

p0002 879-51356

JACKSON, R. L.

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[IAF PAPERS 79-206]

p0010 879-53,90

JACKSON, R. L.

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p0048 879-30860

JONES, R. A.

Inductive energy storage for MPD thrusters

[AIAA 79-0001]

p0029 879-26710

JONES, R. A.

Space Laser Power System

[AIAA PAPERS 79-1013]

p0036 879-26201

JONES, R. A.

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structures

p0014 879-61106

JONES, J. A.

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pole placement design techniques

[AIAA 79-1770]

p0011 879-61106

## K

KAPOSTRA, R. A.

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module

[NASA-CN-78215]

p0021 879-26661

KARLIS, R. P.

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graphite-fiber/aluminum sheet

p0024 879-63323

KAST, G.

Energy analysis of the Solar Power Satellite

p0027 879-66260

KASSING, B.

European technology applicable to Solar Power

Satellite System (SPS)

[IAF PAPERS 79-178]

p0019 879-51335

Interface problems on an SPS solar array blanket

p0046 879-30711

KATZMAN, J. W.

Calculated near characteristic of a large  
spherical reflector antenna

p0007 879-27500

KATZMAN, J. W.

Solar power satellite ground stations

p0017 879-66265

KATZMAN, J. W.

Flexible platform for science and applications

payloads circa 1985

[AIAA 79-0531]

p0009 879-26769

KELLEY, R. J.

New highly conducting coordination compounds

[AC-8064735]

p0040 879-22261

KELLY, T. J.

Technical challenges of large space systems in the  
21st century

[AAS 78-195]

p0001 879-30860

KENDRICK, R. J.

Orbit transfer vehicle propulsion for transfer of  
shuttle-developed large spacecraft to  
geosynchronous orbit

[AIAA 79-0880]

p0029 879-26736

KIERULFF, R. W.

Satellite Power System (SPS) financial management  
scenario

[NASA-CN-157638]

p0041 879-23502

KIRK, R. L.

Dimensional stability investigation -  
Graphite/epoxy truss structure

p0024 879-63320

KISSE, R. L.

First steps to the Solar Power Satellite

p0008 879-27321

Space structure - A key to new opportunities

[AAS PAPERS 79-050]

p0001 879-26769

KRAFFT, R.

Space manipulators - Present capability and future  
potential

[AIAA 79-0903]

p0027 879-26731

Study of membrane reflector technology

[NASA-CN-150720]

p0010 879-27655

KROHN, J. S.

Application of Lagrange Optimization to the drag  
polar utilizing experimental data

[AIAA PAPERS 79-1011]

p0034 879-66335

KROHNKUPF, P. L.

Status of the SPS concept development and  
evaluation program

p0035 879-23519

KUTIA, A. S.

Satellite Power System (SPS) resource requirements  
(critical materials, energy and land)

[NASA-CN-150680]

p0042 879-23492

Satellite Power System (SPS) resource requirements  
(critical materials, energy, and land)

[NASA-CN-162310]

p0044 879-23251

KRAFT, C. C., JR.

The Solar Power Satellite concept - Towards the  
future

p0036 879-27625

KRELLER, G.

Payload capacity of Ariane launched geostationary  
satellites using an electric propulsion system  
for orbit raising

[IAF PAPERS 79-32]

p0010 879-53258

KROHN, J. S.

Large space system automated assembly techniques

[AIAA 79-0934]

p0027 879-26737

KROHN, R. L.

Space radiation effects on spacecraft materials

p0024 879-63320

## L

LAWRENCE, G.

Employment of large structure communication  
satellites for emergency calls

[IAF PAPERS 79-4-36]

p0001 879-53413

## LAW, G. S.

The dimensioning of complex steel meshes in the range of endurance strength and fatigue life  
[AIAA 79-2400] p0007 879-24000

## LAW, G. S., JR.

A programmable power processor for a 25-kw power module  
[AAS 79-2425] p0021 879-24441

## LAW, G. S.

Plasma particle trajectories around spacecraft propelled by ion thrusters  
p0031 879-24029

## LAW, G. S.

Large Advanced Space System /LASS/ Computer Program  
[AIAA 79-2404] p0007 879-24732

## LAW, G. S.

Plasma particle trajectories around spacecraft propelled by ion thrusters  
p0031 879-24029

## LAW, G. S.

Flexible spacecraft control by model error sensitivity suppression  
p0017 879-24833

## LAW, G. S.

General dynamics of a large class of flexible satellite systems  
[IAF PAPER 79-102] p0000 879-51306

## LAW, G. S.

New highly conducting coordination compounds  
[AD-A064735] p0000 879-22261

## LAW, G. S.

Material evaluation for use in long-duration space missions  
p0024 879-41307

## LAW, G. S., JR.

Material degradation in space environments  
[AAS PAPER 79-1508] p0025 879-46700

## LAW, G. S.

A Microwave Radiometer Spacecraft, sensor control requirements and concepts  
[AIAA 79-2777] p0002 879-45473

## LAW, G. S.

Magnetospheric and ionospheric impact of large-scale space transportation with ion engines  
[AD-A067482] p0121 879-21134

## LAW, G. S.

Superglue rotating reflectors in space  
[IAF PAPER 79-112] p0030 879-51331

Satellite solar power station designs with concentrators and radiating control  
[IAF PAPER 79-136] p0039 879-51114

## M

## MAGG, C. S.

Space station thermal control surfaces  
[NASA-CR-361217] p0007 879-22170

## MAGG, C. S.

Preliminary design for a space based orbital transfer vehicle  
[AIAA 79-2407] p0140 879-24733

## MAGG, C. S.

Feasibility study for a satellite frequency modulated radio communication system  
[NASA-CR(P)-1774-001-1] p0004 879-21776

## MAGG, C. S.

Planning Space Shuttle's maiden voyage  
p0000 879-24148

## MAGG, C. S.

Large scale recovery strategies for flexible spacecraft  
[AAS PAPER 79-156] p0038 879-47135

## MAGG, C. S.

Material degradation in space environments  
[AIAA PAPER 79-1508] p0025 879-46700

## MAGG, C. S.

Derivation of the equations of motion for complex structures by symbolic manipulation  
p0007 879-52761

## MAGG, C. S.

Planetary mission requirements, technology and design considerations for a solar electric propulsion stage  
[AIAA 79-2408] p0121 879-24733

## MAGG, C. S.

Employment of large structure communications satellites for emergency calls  
[IAF PAPER 79-136] p0001 879-51307

## MAGG, C. S.

Electrostatically formed antennas  
[AIAA 79-2422] p0011 879-24363

## MAGG, C. S.

Expandable modules for large space structures  
[AIAA 79-2424] p0004 879-24365

## MAGG, C. S.

Space station thermal control surfaces  
[NASA-CR-361217] p0007 879-22170

## MAGG, C. S.

Environmental interaction implications for large space systems  
p0000 879-24027

## MAGG, C. S.

General dynamics of a large class of flexible satellite systems  
[IAF PAPER 79-102] p0000 879-51306

## MAGG, C. S.

The dual-momentum control device for large space systems  
[AIAA 79-2423] p0013 879-24366

The dual-momentum control device for large space systems - An example of distributed system adaptive control  
p0016 879-41306

## MAGG, C. S.

The inclination change for solar sails and low earth orbit  
[AAS PAPER 79-104] p0030 879-47200

## MAGG, C. S.

Critical antenna data power system challenges  
[IAF PAPER 79-136] p0039 879-51307

## MAGG, C. S.

Primary electric propulsion for future space missions  
[AIAA 79-2777] p0002 879-45473

## N

## NAGG, C. S.

First steps to the Solar Power Satellite  
p0036 879-52721

## NAGG, C. S.

Use of a large space structure as an orbital depot for hazardous wastes  
[IAF PAPER 79-136] p0039 879-51307

## NAGG, C. S.

Manned remote work station - Safety and rescue considerations  
[IAF PAPER 79-136] p0039 879-51307

## NAGG, C. S., JR.

The future United States space program: Proceedings of the Twenty-Fifth Anniversary Conference, Houston, Tex., October 30-November 2, 1978, Parts 1 & 2  
p0000 879-24060

## NAGG, C. S.

Geometric model and analysis of rod-like large space structures  
[NASA-CR-361217] p0007 879-22170

## NAGG, C. S.

A combined spacecraft charging and pulsed X-ray simulation facility  
p0010 879-24074

## NAGG, C. S.

Surface secondary measurement system deployable reflecting antennas  
[AIAA 79-2427] p0013 879-24365

## NAGG, C. S.

Solar-pumped lasers for space power transmission  
[AIAA PAPER 79-107] p0019 879-24202

## NAGG, C. S.

Some activities and vehicle concepts envisioned for future earth orbital missions  
p0001 879-22170

## NAGG, C. S.

A combined spacecraft charging and pulsed X-ray simulation facility  
p0010 879-24074

## O

## OAGG, C. S.

Simulated solar concentrators and evaluation support. Phase 2: Non-imaging concentrators for space applications  
[NASA-CR-361217] p0004 879-51306



# TABLE OF CONTENTS

## Subject Categories

*Abstracts in this bibliography are grouped under the following categories*

*page*

### 01 SYSTEMS

Includes mission requirements, focus missions, conceptual studies, technology planning, and systems integration

1 1/A12

### 02 INTERACTIVE ANALYSIS AND DESIGN

Includes computerized technology design and development programs, dynamic analysis techniques, thermal modeling, and math modeling

7 1/B4

### 03 STRUCTURAL CONCEPTS

Includes erectable structures (joints, struts, and columns), deployable platforms and booms, solar sail, deployable reflectors, space fabrication techniques and protrusion processing

9 1/B6

### 04 CONTROL SYSTEMS

Includes new attitude and control techniques, improved surface accuracy measurement and control techniques

13 1/B10

### 05 ELECTRONICS

Includes techniques for power and data distribution

21 1/C4

### 06 ADVANCED MATERIALS

Includes matrix composites, polyimide films and thermal control coatings, and space environmental effects on these materials

23 1/C6

### 07 ASSEMBLY CONCEPTS

Includes automated manipulator techniques, EVA, robot assembly, teleoperators, and equipment installation

27 1/C10

### 08 PROPULSION

Includes propulsion designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts

29 1/C12

### 09 FLIGHT EXPERIMENTS

Includes controlled experiments requiring high vacuum and zero G environment

33 1/D2

### 10 SOLAR POWER SATELLITE SYSTEM

Includes solar power satellite concepts with emphasis upon structures, materials, and controls

35 1/D4

### 1. GENERAL

Includes either state-of-the-art or advanced technology which may apply to Large Space Systems and does not fit within the previous nine categories. Shuttle payload requirements, on-board requirements, data rates, and shuttle interfaces, and publications of conferences, seminars, and workshops will be covered in this area

47 1/E2

<b>SUBJECT INDEX</b> .....	<b>A 1 1/E7</b>
<b>PERSONAL AUTHOR INDEX</b> .....	<b>B 1 1/G9</b>
<b>CORPORATE SOURCE INDEX</b> .....	<b>C 1 2/A5</b>
<b>CONTRACT NUMBER INDEX</b> .....	<b>D 1 2/A10</b>
<b>REPORT/ACCESSION NUMBER INDEX</b> .....	<b>E 1 2/A11</b>

- OKRESS, E. C.  
Solar thermal aerostat research station /STARS/  
[IAF PAPER 79-35] p0691 A79-53261
- OLSON, E. E.  
Planetary mission requirements, technology and  
design considerations for a solar electric  
propulsion stage  
[AIAA 79-0908] p0029 A79-34735
- OWELL, E. P.  
Thermal control design analysis of an on-orbit  
assembly space-raft  
[AIAA 79-0917] p0007 A79-34740
- OWEN, W. A.  
Magnetic shielding of large high-power satellite  
solar arrays using internal currents  
p0043 A79-24926

## P

- PALMER, W. E.  
Large solid deployable reflector  
[AIAA 79-0925] p0009 A79-34746
- PARKER, L. W.  
Effects of plasma sheath on solar power satellite  
array  
[AIAA PAPER 79-1507] p0037 A79-06699  
Plasma sheath effects and voltage distributions of  
large high-power satellite solar arrays  
p0043 A79-24024  
Magnetic shielding of large high-power satellite  
solar arrays using internal currents  
p0043 A79-24026
- PELOUCH, J. J., JR.  
Space propulsion technology overview  
[AIAA 79-0860] p0029 A79-34704  
Low-thrust chemical orbit transfer propulsion  
[AIAA PAPER 79-1182] p0030 A79-39815  
Low-thrust chemical orbit transfer propulsion  
[NASA-TN-79190] p0031 A79-25129
- PIKUZ, S. A.  
Anomalous intensity ratios of the resonance to  
intercombination lines of He-like ions in Nd-  
and CO<sub>2</sub>-laser-produced plasma  
p0047 A79-24021
- POLIANKOVA, E. M.  
Assessment of the errors of an analytical method  
of calculating the geocentric trajectories of a  
solar sail  
p0018 A79-53063
- POSSANSKY, H. A.  
Attitude control of agile flexible spacecraft  
[AIAA 79-1739] p0015 A79-45381
- POSPISIL, M.  
A space power station without movable parts  
[IAF PAPER 79-177] p0039 A79-53337
- POWELL, E. V.  
Space-based radio telescopes and an orbiting  
deep-space relay station  
[AIAA 79-0947] p0001 A79-34762
- PREVO, E. M.  
Graphite fiber reinforced glass matrix composites  
for aerospace applications  
p0023 A79-43234
- POTNEY, Z.  
An economic analysis of a commercial approach to  
the design and fabrication of a space power system  
[AIAA 79-0914] p0036 A79-34737  
An economic analysis of a commercial approach to  
the design and fabrication of a space power system  
[NASA-TN-79153] p0040 A79-22193
- PYCHON, C. E.  
Dimensional stability investigation -  
Graphite/epoxy truss structure  
p0024 A79-43330

## Q

- QUINCY, D.  
Solar-pumped lasers for space power transmission  
[AIAA PAPER 79-1015] p0037 A79-38202
- QUITMAN, E.  
Canadian development of large deployable solar  
arrays for communications spacecraft  
p0050 A79-30754

## R

- RABO, V.  
Solar thermoelectric power generation for Mercury

- orbiter missions  
[AIAA 79-0915] p0029 A79-34739
- RAINEY, R. E.  
Autonomous mechanical assembly on the space  
shuttle: An overview  
[NASA-CN-158818] p0028 A79-28201
- RATHJEN, S. M.  
Computer modeling for a space power transmission  
system  
p0038 A79-51941
- RAVINDRAN, R.  
Space manipulators - Present capability and future  
potential  
[AIAA 79-0903] p0027 A79-34731
- RAWLIN, V. E.  
Increased capabilities of the 30-cm diameter Hg  
ion thruster  
[AIAA 79-0910] p0030 A79-34774
- REHITZEN, J.  
Energy analysis of the Solar Power Satellite  
p0037 A79-42160
- REDDY, A. S. S. R.  
Decoupling control of a long flexible beam in orbit  
[AAS PAPER 79-158] p0036 A79-47236  
The dynamics and control of large flexible space  
structures, 2. Part A: Shape and orientation  
control using point actuators  
[NASA-CN-158684] p0018 A79-25122
- REDDY, J.  
Effects of electron irradiation on large  
insulating surfaces used for European  
Communications Satellites  
p0023 A79-36190  
Effects of electron irradiation on large  
insulating surfaces used for European  
Communications Satellites  
p0025 A79-24036
- REDMOND, P. J.  
Electrostatically forced antennas  
[AIAA 79-0922] p0013 A79-34703
- REHBERG, J. J.  
A space-based orbital transfer vehicle - Bridge to  
the future  
[AIAA 79-0865] p0047 A79-34705  
Preliminary design for a space based orbital  
transfer vehicle  
[AIAA 79-0897] p0048 A79-34728
- REIFF, P.  
Space environmental effects and the solar power  
satellite  
p0043 A79-24028
- REINHARTZ, M. E.  
European aspects of Solar Satellite Power systems  
p0035 A79-31923
- RENNER, G.  
Attitude control by solar sailing - A promising  
experiment with OTS-2  
p0014 A79-36189
- RENSHALL, J. T.  
Canadian development of large deployable solar  
arrays for communications spacecraft  
p0050 A79-30754
- REYNOLDS, R. E.  
Computer modeling for a space power transmission  
system  
p0038 A79-51941
- ROOTE, W. E.  
An evolutionary solar power satellite program  
[AAS PAPER 79-153] p0036 A79-21265
- ROCK, E. E.  
Long interface docking for large space structure  
assembly  
[AIAA 79-0954] p0014 A79-34765  
Control of large flexible space structures using  
pole placement design techniques  
[AIAA 79-1738] p0015 A79-45380
- ROSLY, E. C.  
Cost comparisons for the use of nonferrous  
materials in space manufacturing of large  
structures  
[IAF PAPER 79-115] p0038 A79-51302
- ROBINSON, G. A., JR.  
LDEF transverse flat plate heat pipe experiment  
/S1005/  
[AIAA PAPER 79-1077] p0033 A79-38053
- ROCHE, J. C.  
Large space system - Charged particle environment  
interaction technology  
[AIAA 79-0913] p0043 A79-34775

- Large space system: Charged particle environment interaction technology  
[NASA-TN-79156] p0049 879-22188
- RUDGE, A. W.  
A review of some critical aspects of satellite power systems p0035 879-31921
- RUDOLPH, L. K.  
Inductive energy storage for MPD thrusters  
[AIAA 79-0881] p0029 879-34718
- RUESCH, D.  
New flexible substrates with anti-charging layers for advanced lightweight solar arrays p0025 879-30717
- RUNGE, F. C.  
Deployable multi-payload platform  
[AIAA 79-0528] p0009 879-34748
- RUSSILL, R. A.  
NASA technology for large space antennas p0002 879-52674
- RUTH, J.  
Solar power satellites for Europe  
[IAF PAPER 79-173] p0039 879-53334
- ROSGOVN: A potential European contribution in developing large solar generators suitable for growing power levels up to GWS-systems p0044 879-30752

## S

- SATIN, A. L.  
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[AAS PAPER 79-155] p0016 879-47234
- SATAGE, C. J.  
Development of a movable, thermally conducting joint for application to deployable radiators p0012 879-31314
- SCHARCHTER, B. R.  
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[AIAA 79-1740] p0015 879-45392
- SCHAEFER, W.  
Lightweight deployable microwave satellite antennas - Steel, concepts and related technology problems  
[IAF PAPER 79-211] p0010 879-51361
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Magnetospheric and ionospheric impact of large-scale space transportation with ion engines  
[AD-8065462] p0031 879-23134
- SCOTT-MONCK, J. A.  
The JIL space photovoltaic program p0045 879-32643
- SCOTT, B. B.  
Space station thermal control surfaces  
[NASA-CR-161217] p0008 879-22178
- SEIDL, W. A.  
A combined spacecraft charging and pulsed X-ray simulation facility p0050 879-24054
- SELLAPPAN, B. G.  
The dynamics and optimal control of spinning spacecraft with movable telescoping appendages p0019 879-29222
- SELTZER, S. B.  
Dynamics and control of large space structures - An overview p0017 879-49832
- SERENE, M. V.  
Effects of electron irradiation on large insulating surfaces used for European Communications Satellites p0023 879-36190
- SERENE, M. V. B.  
Effects of electron irradiation on large insulating surfaces used for European Communications Satellites p0025 879-24036
- SE'AN, J. B.  
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- SHEPPARD, F. R.  
Global services systems - Space communication  
[AIAA 79-0946] p0408 879-34761
- SIMONS, L.  
New methods for the conversion of solar energy to H<sub>2</sub> F. and laser power  
[AIAA PAPER 79-1416] p0036 879-38846

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Materials degradation in space environments  
[AIAA PAPER 79-1506] p0025 879-46700
- SKELTON, R. E.  
Observability measures and performance sensitivity in the model reduction problem p0018 879-37287
- On cost-sensitivity controller design method for uncertain dynamic systems p0017 879-49835
- Social truncation for flexible spacecraft  
[AIAA PAPER 79-1765] p0007 879-52555
- SKOBLIN, I. I.  
Anomalous intensity ratios of the resonance to intercombination lines of He-like ions in He- and CO<sub>2</sub>-laser-produced plasma p0047 879-24021
- SLIPER, L. W., JR.  
Synchronous orbit power technology needs  
[AIAA 79-0916] p0048 879-34739
- Synchronous orbit power technology needs  
[NASA-TN-80280] p0003 879-22174
- SLYER, F.  
Large space system automated assembly technique  
[AIAA 79-0939] p0027 879-34757
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Future programs in space  
[AAS 79-100] p0008 879-34665
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Solar thermal aerostat research station /STARS/  
[IAF PAPER 79-85] p0091 879-53261
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Teleoperator system for management of satellite deployment and retrieval p0027 879-40539
- STAUBER, M. C.  
Environmental interaction implications for large space systems p0008 879-24027
- STEVENS, R. J.  
Large space system - Charged particle environment interaction technology  
[AIAA 79-0913] p0048 879-34775
- Large space system: Charged particle environment interaction technology  
[NASA-TN-79156] p0049 879-22188
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European technology applicable to Solar Power Satellite System /SPS/  
[IAF PAPER 79-174] p0039 879-53335
- STOKES, J. W.  
Construction in space - Toward a fresh definition of the man/machine relation p0027 879-34985
- STORNFEL, D.  
Orbital Test Satellite (OTS) thermal design and in-orbit performance p0051 879-31270
- Orbital assessment of OTS thermal performance p0051 879-31271
- The OTS hydrazine reaction control system thermal conditioning technique p0051 879-31306
- SON, F. K.  
Environmental interaction implications for large space systems p0008 879-24027
- SON, K. C.  
New energy conversion techniques in space, applicable to propulsion  
[AIAA PAPER 79-1338] p0037 879-40490
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Solar thermoelectric power generation for Mercury orbiter missions  
[AIAA 79-0915] p0029 879-34738
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Stability and control of future spacecraft systems  
[AIAA 79-0864] p0014 879-34766

## T

- TAKAHASHI, A.  
A method of controlling orbits of geostationary satellites with minimum fuel consumption p0047 879-30782
- TANG, S.  
A nonlinear stress-strain law for metallic meshes  
[AIAA 79-0936] p0023 879-34754

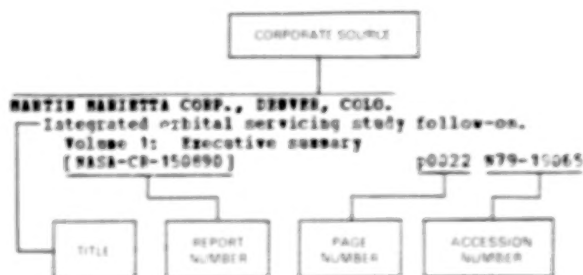
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Mastpole /Mast/Column/ deployable reflector concept  
development for 30 to 100 meter antenna  
[AIAA 79-0935] p0009 179-34753
- TAUSSIG, E.**  
Solar-pumped lasers for space power transmission  
[AIAA PAPER 79-1015] p0017 179-30202
- TENDAN, P. F.**  
Primary electric propulsion for future space  
missions  
[NASA-TN-79141] p0030 179-22190
- TEVELL, J. E.**  
Teleoperator system for management of satellite  
deployment and retrieval  
p0027 179-30539
- THOMASSEN, J. P.**  
Space radiation effects on spacecraft materials  
p0024 179-41304
- TRIGGS, E.**  
European technology applicable to Solar Power  
Satellite Systems /SPS/  
[IAF PAPER 79-174] p0039 179-51335
- TRELLA, E.**  
European aspects of Solar Satellite Power systems  
p0035 179-31623
- TREYLL, E.**  
Trends in the design of future communications  
satellite systems  
[IAF PAPER 79-107] p0003 179-31009
- TSCHULENA, G.**  
Energy for the year 2000 - The SPS concept  
p0038 179-40026
- U**
- UNDERHILL, A. E.**  
New highly conducting coordination compounds  
[AD-A064735] p0040 179-22261
- V**
- VANDENBERG, F. A.**  
On-orbit assembly of Large Space Structures /LSS/  
using an autonomous rendezvous and docking  
[AAS PAPER 79-100] p0027 179-47201
- VIDALSAINT ANDRE, E.**  
Feasibility study for a satellite frequency  
modulated radio communication system  
[ESA-CE(P)-1151-VOL-1] p0004 179-27376
- VINOGRADOV, A. V.**  
Anomalous intensity ratios of the resonance to  
intercombination lines of He-like ions in He-  
and CO<sub>2</sub>-laser-produced plasma  
p0047 179-24021
- VISHEN, P. S.**  
Satellite clusters  
p0002 179-51149
- W**
- WADE, W. D.**  
An approach toward the design of large diameter  
offset-fed antennas  
[AIAA 79-0538] p0010 179-34756  
The application of metal-matrix composites to  
spaceborne parabolic antennas  
p0024 179-41322
- WALTZ, J. E.**  
Load concentration due to missing members in  
planar faces of a large space truss  
[NASA-TN-1522] p0008 179-33500
- WATKINS, E. E.**  
Construction in space - Toward a fresh definition  
of the man/machine relation  
p0027 179-34985
- WESTPHAL, E.**  
Solar power satellites for Europe  
[IAF PAPER 79-173] p0039 179-51334  
MOSEGEN: A potential European contribution to  
developing large solar generators suitable for  
growing power levels up to SPS-systems  
p0044 179-39752
- WHITESIDE, J.**  
A nonlinear stress-strain law for metallic meshes  
[AIAA 79-0936] p0023 179-34754
- WILLIAMS, J. E.**  
New highly conducting coordination compounds  
[AD-A064735] p0040 179-22261
- WILLIAMS, E.**  
Thermally stable, thin, flexible  
graphite-fiber/aluminum sheet  
p0024 179-41323
- WINSTON, E.**  
Winston solar concentrators and evaluation  
support. Phase 2: Non-imaging concentrators  
for space applications  
[NASA-CR-142279] p0044 179-31764
- WISE, J.**  
Solar photovoltaic research and development  
program of the Air Force Aero Propulsion  
Laboratory  
p0045 179-32462
- WOLBERS, E. L.**  
Global services systems - Space communication  
[AIAA 79-0946] p0008 179-34761
- WOLFE, M. G.**  
Orbit transfer needs of the late 1980s and the 1990s  
[IAF PAPER 79-10] p0049 179-51256
- WOODCOCK, G. E.**  
Solar Power Satellite system definition  
p0035 179-31620  
Solar power satellites: The Engineering Challenges  
p0044 179-30750
- WOODS, A. A., JR.**  
An approach toward the design of large diameter  
offset-fed antennas  
[AIAA 79-0938] p0010 179-34756
- WU, Y. W.**  
Control of large flexible space structures using  
pole placement design techniques  
[AIAA 79-1738] p0015 179-45300
- Y**
- YOC, C. E.**  
Optimization of triangular faced truss columns  
with tubular compression members for space  
application  
p0010 179-46062
- YOUNG, L. E.**  
SPS solar array development testing  
p0010 179-51406
- Z**
- ZYLUS, P. A.**  
Predictable platforms for science and applications  
payloads circa 1985  
[AIAA 79-0911] p0009 179-34749

# CORPORATE SOURCE INDEX

TECHNOLOGY FOR LARGE SPACE SYSTEMS/A Special Bibliography (Suppl 2)

JANUARY 1980

## Typical Corporate Source Index Listing



The title of the document is used to provide a brief description of the subject matter. The page number and NASA accession number are included in each entry to assist the user in locating the abstract.

## A

- ARG-TELEFUNKEN, WEDL (WEST GERMANY).**  
New flexible substrates with anti-charging layers for advanced lightweight solar arrays  
[NASA-CR-161217] p0025 N79-30717
- ARBOJET ELECTROSYSTEMS CO., AZUSA, CALIF.**  
Space station thermal control surfaces  
[NASA-CR-161217] p0006 N79-22178
- AEROSPACE CORP., EL SEGUNDO, CALIF.**  
Communication architecture for large constellation platform  
[IAF PAPER 79-300] p0011 N79-53804
- ATMOSPHERIC AND IONOSPHERIC IMPACT OF LARGE-SCALE SPACE TRANSPORTATION WITH ION ENGINES**  
[AD-A069882] p0031 N79-23134
- ENVIRONMENTAL FACTORS OF POWER SATELLITES**  
[SAMSO-79-79-66] p0043 N79-28213
- AIR FORCE AERO PROPULSION LAB., WRIGHT-PATTERSON AFB, OHIO.**  
Solar photovoltaic research and development program of the Air Force Aero Propulsion Laboratory  
p0045 N79-32642
- AIR FORCE GEOPHYSICS LAB., HANDSCOM AFB, MASS.**  
The calculation of spacecraft potentials: Comparison between theory and observation  
p0050 N79-28019
- ASTRO RESEARCH CORP., CARPINTERIA, CALIF.**  
Expandable modules for large space structures  
[AIAA 79-0024] p0005 N79-34705
- FOLDABLE BEAM**  
[NASA-CASE-LAB-12077-1] p0011 N79-25425
- STUDY OF BEAMREFLECTOR TECHNOLOGY**  
[NASA-CR-150729] p0018 N79-27655
- ## B
- BENDIX CORP., TETERBOL, N. J.**  
Space construction base control system  
[NASA-CR-161298] p0018 N79-29215
- BOEING AEROSPACE CO., SEATTLE, WASH.**  
Computer modeling for a space power transmission system  
p0038 N79-51941
- SYSTEM DEFINITION SPACE BASED POWER CONVERSION SYSTEMS: EXECUTIVE SUMMARY**  
[NASA-CR-150299] p0040 N79-22616
- SYSTEM DEFINITION SPACE-BASED POWER CONVERSION SYSTEMS**  
[NASA-CR-150298] p0041 N79-23089

- Plasma particle trajectories around spacecraft propelled by ion thrusters**  
p0031 N79-24029
- Design fabrication and test of graphite/polyimide composite joints and attachments for advanced aerospace vehicles**  
[NASA-CR-150980] p0111 N79-24066
- Solar power satellites: The Engineering Challenges**  
p0044 N79-30750
- BRITISH AEROSPACE DYNAMICS GROUP, BRISTOL (ENGLAND).**  
A study on solar arrays for programmes leading from the extension of Spacelab towards space platforms  
p0004 N79-30748

## C

- CHICAGO UNIV., ILL.**  
Winston solar concentrators and evaluation support. Phase 2: Non-imaging concentrators for space applications  
[NASA-CR-162279] p0044 N79-31764
- CINCINNATI UNIV., OHIO.**  
Geometric model and analysis of rod-like large space structures  
[NASA-CR-158509] p0008 N79-23128
- COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION (U. S. SENATE).**  
NASA authorization for fiscal year 1980, part 2  
[GPO-43-135] p0050 N79-25927
- NASA authorization for fiscal year 1980, part 3**  
[GPO-44-885] p0050 N79-30093
- COMMITTEE ON ENERGY AND NATURAL RESOURCES (U. S. SENATE).**  
Solar Power Satellite Research, Development, and Demonstration Program Act of 1978  
[GPO-35-994] p0044 N79-32726
- COMMITTEE ON SCIENCE AND TECHNOLOGY (U. S. HOUSE).**  
Solar power satellite  
[GPO-45-997] p0043 N79-29212
- NASA authorization, 1980, volume 1, part 3**  
[GPO-46-422] p0050 N79-31084
- NASA authorization, 1980, volume 1, part 4**  
[GPO-46-423] p0050 N79-31085
- CONSAT LABS., CLARKSBURG, MD.**  
Synchronous orbit power technology needs  
[AIAA 79-0916] p0048 N79-34739
- CONSTRUCCIONES AERONAUTICAS S.A., MADRID (SPAIN).**  
Study of high stability structural systems: Pre-phase A  
[DT-885-5] p0012 N79-30504

## D

- DEPARTMENT OF ENERGY, WASHINGTON, D. C.**  
Satellite power system: Concept development and evaluation program, reference system report  
[DOE/TR-0023] p0039 N79-21538
- DOERNIER-WERKE S.M.B.R., FRIEDRICHSHAFEN (WEST GERMANY).**  
Development of a movable, thermally conducting joint for application to deployable radiators  
p0012 N79-31314

## E

- ECOL, INC., PRINCETON, N. J.**  
Space-based solar power conversion and delivery systems study. Volume 1: Executive summary  
[NASA-CR-150294] p0040 N79-22617
- Space-based solar power conversion and delivery systems study. Volume 2: Engineering analysis**  
[NASA-CR-150295] p0040 N79-22618

Space-based solar power conversion and delivery systems study. Volume 3: Microwave power transmission studies  
[NASA-CR-150296] p0040 W79-22419

Space-based solar power conversion and delivery systems study. Volume 4: Energy conversion systems studies  
[NASA-CR-150297] p0046 W79-22420

EMMO RAUMFAHRTTECHNIK G.M.B.H., BREMEN (WEST GERMANY).  
Orbital Test Satellite (OTS) thermal design and in-orbit performance p0051 W79-31270

The OTS hydrazine reaction control system thermal conditioning technique p0051 W79-31306

EUROPEAN SPACE AGENCY, WOORDSWIJ (NETHERLANDS).  
Interface problems on an SPS solar array blanket p0044 W79-30751

EUROPEAN SPACE AGENCY, PARIS (FRANCE).  
Effects of electron irradiation on large insulating surfaces used for European Communications Satellites p0025 W79-24036

Photovoltaic generators in space [SP-140] p0044 W79-30730

EUROPEAN SPACE RESEARCH AND TECHNOLOGY CENTER, WOORDSWIJ (NETHERLANDS).  
Orbital assessment of OTS thermal performance p0051 W79-31271

## G

GARRETT CORP., LOS ANGELES, CALIF.  
Systems definition space-based power conversion systems  
[NASA-CR-150268] p0041 W79-23483

GENERAL DYNAMICS/CONVAIR, SAN DIEGO, CALIF.  
Cost comparisons for the use of nonterrestrial materials in space manufacturing of large structures  
[IAP PAPER 79-115] p0038 W79-53302

Development of a beam builder for automatic fabrication of large composite space structures p0011 W79-22563

Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS), part 3. Volume 2: Study results  
[NASA-CR-160288] p0011 W79-29203

GENERAL ELECTRIC CO., PHILADELPHIA, PA.  
Mission specification for three generic mission classes  
[NASA-CR-159048] p0004 W79-23126

GENERAL RESEARCH CORP., SANTA BARBARA, CALIF.  
Electrostatically formed antennas  
[AIAA 79-0922] p0013 W79-34743

GRUMMAN AEROSPACE CORP., BETHPAGE, N.Y.  
New space initiatives through large generic structures  
[IAP PAPER 79-208] p0002 W79-53358

Manned remote work station - Safety and rescue considerations  
[IAP PAPER 79-A-19] p0027 W79-53421

Space-based solar power conversion and delivery systems study. Volume 2: Engineering analysis  
[NASA-CR-150295] p0040 W79-22418

Environmental interaction implications for large space systems p0008 W79-24027

Space fabrication demonstration system, technical volume  
[NASA-CR-161286] p0011 W79-29213

Space fabrication demonstration system: Executive summary  
[NASA-CR-161287] p0011 W79-29214

## H

HAMILTON STANDARD, HARTFORD, CONN.  
Concept definition for an extended duration orbiter ECLSS  
[NASA-CR-160164] p0049 W79-23666

HOWARD UNIV., WASHINGTON, D. C.  
Decoupling control of a long flexible beam in orbit  
[AAS PAPER 79-150] p0016 W79-47236

The dynamics and control of large flexible space structures, 2. Part 1: Shape and orientation control using point actuators

[NASA-CR-158684] p0018 W79-25122

The dynamic and optimal control of spinning spacecraft with movable telescoping appendages p0019 W79-79222

## I

IIT RESEARCH INST., CHICAGO, ILL.  
Space radiation effects on composite matrix materials - Analytical approaches p0023 W79-43305

## J

JET PROPULSION LAB., CALIFORNIA INST. OF TECH., PASADENA.  
Inductive energy storage for MPD thrusters  
[AIAA 79-0883] p0024 W79-34718

Planetary mission requirements, technology and design considerations for a solar electric propulsion stage  
[AIAA 79-3998] p0029 W79-34735

Solar thermoelectric power generation for Mercury orbiter missions  
[AIAA 79-0915] p0029 W79-34738

Deployable antenna technology development for the Large Space Systems Technology program  
[AIAA 79-0932] p0009 W79-34750

A self pulsed laser ranging system under development at 'JPL'  
[AIAA 79-0934] p0013 W79-34752

Space-based radio telescopes and an orbiting deep-space relay station  
[AIAA 79-0947] p0001 W79-34762

Stability and control of future spacecraft systems  
[AIAA 79-0864] p0014 W79-34766

Attitude control requirements for future space systems  
[AIAA 79-0951] p0016 W79-34767

Advanced teleoperators p0027 W79-34982

Control of large flexible space structures using pole placement design techniques  
[AIAA 79-1738] p0015 W79-45380

Optimal local control of flexible structures  
[AIAA 79-1740] p0015 W79-45382

NASA technology for large space antennas p0002 W79-52674

Pointing and control system enabling technology for future automated space missions  
[NASA-CR-158511] p0018 W79-22177

Study of membrane reflector technology  
[NASA-CR-158729] p0018 W79-27655

Autonomous mechanical assembly on the space shuttle: An overview  
[NASA-CR-158818] p0020 W79-28201

Winston solar concentrators and evaluation support. Phase 2: Non-imaging concentrators for space applications  
[NASA-CR-162279] p0044 W79-31764

The JPL space photovoltaic program p0045 W79-32643

## K

KENTRON INTERNATIONAL, INC., HAMPTON, VA.  
Preliminary design for a space based orbital transfer vehicle  
[AIAA 79-0897] p0048 W79-34728

KOTIN (ALLAN D.) ECONOMIC CONSULTANTS, LOS ANGELES, CALIF.  
Satellite Power System (SPS) resource requirements (critical materials, energy and land)  
[NASA-CR-158680] p0042 W79-23492

## L

LINCOLN LAB., MASS. INST. OF TECH., LEXINGTON.  
The critical satellite technical issues of future pervasive broadband low-cost communication networks  
[IAP PAPER 79-102] p0003 W79-53406

LITTLE (ARTHUR D.), INC., CAMBRIDGE, MASS.  
Space-based solar power conversion and delivery systems study. Volume 4: Energy conversion systems studies  
[NASA-CR-150297] p0040 W79-22420



## LOCKHEED MISSILES AND SPACE CO., PALO ALTO, CALIF.

- New energy conversion techniques in space,  
applicable to propulsion p0017 A79-40490  
[AIAA PAPER 79-1138]
- LOCKHEED MISSILES AND SPACE CO., SUNNYVALE, CALIF.  
SFP solar array development testing p0030 A79-51904  
Automatic in-orbit assembly of large space  
structures p0028 A79-22542

## M

## MARTIN MARIETTA AEROSPACE, DENVER, COLO.

- Control of large flexible space structures using  
pole placement design techniques p0015 A79-45360  
[AIAA 79-0928]
- MATHEMATICAL SCIENCES NORTHWEST, INC., SEATTLE, WASH.  
Solar-pumped lasers for space power transmission  
[AIAA PAPER 79-1015] p0037 A79-38292
- MCDONNELL-DOUGLAS AERONAUTICS CO., HUNTINGTON  
BEACH, CALIF.  
Deployable multi-payload platform p0009 A79-34748  
[AIAA 79-0928]  
Global services system - Space communication  
[AIAA 79-0946] p0438 A79-34761  
Construction of large space structures  
[IAF PAPER 79-106] p0010 A79-53298  
Graphite/polyimide state-of-the-art panel  
discussion p0029 A79-30328

## N

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,  
WASHINGTON, D. C.

- Planning Space Shuttle's maiden voyage p0048 A79-44248  
A technology base for near-term space platforms  
[IAF PAPER 79-110] p0002 A79-53300  
Orbital demonstration - The prelude to large  
operational structures in space p0002 A79-53357  
[IAF PAPER 79-207]  
New space initiatives through large generic  
structures p0002 A79-53358  
[IAF PAPER 79-208]  
Satellite power system: Concept development and  
evaluation program, reference system report  
[DOE/79-002] p0014 A79-21538  
Some activities and vehicle concepts envisioned  
for future earth orbital missions p0003 A79-22125  
Preliminary environmental assessment for the  
Satellite Power System (SPS). Volume 2:  
Detailed assessment p0043 A79-24436  
[NASA-TN-80155]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, AMES  
RESEARCH CENTER, MOFFETT FIELD, CALIF.

- SOLARES - A new hope for solar energy p0047 A79-33992

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,

- GODDARD SPACE FLIGHT CENTER, GREENBELT, MD.  
Synchronous orbit power technology needs p0048 A79-34719  
[AIAA 79-0916]

- Synchronous orbit power technology needs p0003 A79-22174  
[NASA-TN-80280]

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,

- LYNDON B. JOHNSON SPACE CENTER, HOUSTON, TEX.

- The Solar Power Satellite concept - Towards the  
future p0036 A79-31925

- Deployable multi-payload platform p0009 A79-34748  
[AIAA 79-0928]

- Orbit transfer operations for the Space Shuttle  
era p0045 A79-53255  
[IAF PAPER 79-29]

- Construction of large space structures p0010 A79-53298  
[IAF PAPER 79-106]

- The 13th Aerospace Mechanisms Symposium p0049 A79-22519  
[NASA-CP-20811]

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,

- LANGLEY RESEARCH CENTER, HAMPTON, VA.

- Design and operations technologies - Integrating  
the pieces p0001 A79-34702  
[AIAA 79-0858]

- A space-based orbital transfer vehicle - Bridge  
to the future p0047 A79-34795  
[AIAA 79-0865]

- Preliminary design for a space based orbital  
transfer vehicle p0048 A79-34728  
[AIAA 79-0897]  
A technology program for large area space systems  
[AIAA 79-0921] p0001 A79-34742  
The dual-momentum control device for large space  
systems p0013 A79-34744  
[AIAA 79-0923]  
Expandable modules for large space structures  
[AIAA 79-0924] p0009 A79-34745  
Rectable platforms for science and applications  
payloads circa 1985 p0004 A79-34749  
[AIAA 79-0931]  
Deployable antenna technology development for  
the Large Space System Technology program  
[AIAA 79-0932] p0004 A79-34750  
Calculated scan characteristics of a large  
spherical reflector antenna p0007 A79-37100

- The dual momentum control device for large space  
systems - An example of distributed system  
adaptive control p0014 A79-61106

- Stability bounds for the control of large space  
structures p0014 A79-61699

- Graphite fiber reinforced glass matrix  
composites for aerospace applications p0023 A79-63234

- A Microwave Radiometer Spacecraft, some control  
requirements and concepts p0002 A79-45423  
[AIAA 79-1777]

- Decoupling control of a long flexible beam in  
orbit p0016 A79-47246  
[AIAA PAPER 79-158]

- NASA technology for large space antennas p0002 A79-52674

- A technology base for near-term space platforms  
[IAF PAPER 79-110] p0002 A79-53300

- Foldable beam p0011 A79-25425  
[NASA-CASR-LSP-12077-1]

- Graphite/Polyimide Composites p0025 A79-30297  
[NASA-CP-2073]

- Load concentration due to joining members in  
planar faces of a large space truss p0008 A79-33500  
[NASA-TN-1522]

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,

## LEWIS RESEARCH CENTER, CLEVELAND, OHIO.

- Space propulsion technology overview p0029 A79-34704  
[AIAA 79-0860]

- An economic analysis of a commercial approach to  
the design and fabrication of a space power  
system p0038 A79-34737  
[AIAA 79-0914]

- Increased capabilities of the 10-cm diameter  
ion thruster p0030 A79-34774  
[AIAA 79-0910]

- Large space system - Charged particle  
environment interaction technology p0048 A79-34775  
[AIAA 79-0913]

- Low-thrust chemical orbit transfer propulsion  
[AIAA PAPER 79-1182] p0030 A79-34715

- Results from Symposium on Future Orbital Power  
Systems Technology Requirements p0038 A79-51891

- Large space system: Charged particle  
environment interaction technology p0049 A79-22188  
[NASA-TN-79156]

- Primary electric propulsion for future space  
missions p0030 A79-22190  
[NASA-TN-79141]

- Results from Symposium on Future Orbital Power  
systems technology requirements p0008 A79-22191  
[NASA-TN-79125]

- An economic analysis of a commercial approach to  
the design and fabrication of a space power  
system p0040 A79-22193  
[NASA-TN-79153]

- Spacecraft Charging Technology, 1979 p0050 A79-24001  
[NASA-CP-20711]

- Low-thrust chemical orbit transfer propulsion  
[NASA-TN-79190] p0031 A79-25129

- The NASA Lewis Research Center program in space  
solar cell research and technology p0045 A79-32641

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,

## MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALA.

- Construction in space - Toward a fresh  
definition of the man/machine relation

p0027 879-34535  
LDIF transverse flat plate heat pipe experiment  
/ST005/  
[AIAA PAPER 79-1077] p0033 879-38053  
SEP solar array development testing p0030 879-51994  
Magnetic shielding of large high-power-satellite  
solar arrays using internal currents p0043 879-24026  
A programmable power processor for a 25-kW power  
module p0021 879-24471  
[NASA-TN-78215] p0021 879-24471  
Platforms in space: Evolutionary trends p0005 879-10879  
NORTH CAROLINA STATE UNIV., RALEIGH.  
Calculated scan characteristics of a large  
spherical reflector antenna p0007 879-37100

## O

OLD DOMINION UNIV. RESEARCH FOUNDATION, NORFOLK, VA.  
Stability bounds for the control of large space  
structures p0014 879-41699

## P

PARKER (LEY W.), INC., CONCORD, MASS.  
Effects of plasma sheath on solar power  
satellite array p0037 879-46699  
[AIAA PAPER 79-1507] p0037 879-46699  
Plasma sheath effects and voltage distributions  
of large high-power satellite solar arrays p0043 879-24024  
PBC ENERGY ANALYSIS CO., MCLEAN, VA.  
Satellite Power System (SPS) resource  
requirements (critical materials, energy and  
land) p0042 879-23497  
[NASA-CN-150680] p0042 879-23497  
Potential of laser for SPS power transmission  
[NASA-CN-157432] p0042 879-23496  
Satellite Power System (SPS) mapping of  
exclusion areas for rectenna sites p0043 879-23499  
[NASA-CN-157435] p0043 879-23499  
Satellite Power System (SPS) military implications  
[NASA-CN-157436] p0042 879-23500  
Satellite Power System (SPS) financial  
management scenarios p0043 879-23502  
[NASA-CN-157438] p0043 879-23502  
Satellite Power System (SPS) resource  
requirements (critical materials, energy, and  
land) p0044 879-31251  
[NASA-CN-162310] p0044 879-31251

## R

RAYTHEON CO., WATLAND, MASS.  
Space-based solar power conversion and delivery  
systems study. Volume 3: Microwave power  
transmission studies p0040 879-22619  
[NASA-CN-150296] p0040 879-22619  
RICE UNIV., HOUSTON, TEX.  
Space environmental effects and the solar power  
satellite p0043 879-24028  
ROCKWELL INTERNATIONAL CORP., DOWNY, CALIF.  
Satellite Power Systems (SPS) concept definition  
study exhibit C. Volume 3: Experimental  
verification definition p0041 879-22632  
[NASA-CN-161214] p0041 879-22632  
Satellite Power Systems (SPS) concept definition  
study, exhibit C. Volume 5: Special emphasis  
studies p0041 879-22633  
[NASA-CN-161215] p0041 879-22633  
Satellite Power Systems (SPS) concept definition  
study, exhibit C. Volume 6: In-depth element  
investigation p0041 879-22634  
[NASA-CN-161216] p0041 879-22634  
Satellite Power Systems (SPS) concept definition  
study, exhibit C. Volume 1: Executive summary p0041 879-23484  
[NASA-CN-161218] p0041 879-23484  
Satellite Power Systems (SPS) concept definition  
study, exhibit C. Volume 2, part 1: System  
engineering p0041 879-23485  
[NASA-CN-161219] p0041 879-23485  
Satellite Power Systems (SPS) concept definition  
study, exhibit C. Volume 2, part 2: System  
engineering, cost and programming

[NASA-CN-161220] p0042 879-23486  
Satellite Power Systems (SPS) concept definition  
study, exhibit C. Volume 2, part 2: System  
engineering, cost and programming, appendices  
[NASA-CN-161221] p0042 879-23487  
Satellite Power Systems (SPS) concept definition  
study, exhibit C. Volume 4: Transportation  
analysis p0042 879-23488  
[NASA-CN-161222] p0042 879-23488  
Satellite Power Systems (SPS) concept definition  
study, exhibit C. Volume 7: System/subsystem  
requirements data book p0042 879-23489  
[NASA-CN-161223] p0042 879-23489  
Space construction system analysis. Part 1:  
Executive summary p0004 879-30264  
[NASA-CN-160295] p0004 879-30264  
Space construction system analysis study. Task  
3: Construction system shuttle integration p0010 879-30267  
[NASA-CN-160296] p0010 879-30267  
Space construction data base p0004 879-30268  
[NASA-CN-160297] p0004 879-30268  
Space construction system analysis. Part 1:  
Executive summary. Special emphasis studies p0004 879-30269  
[NASA-CN-160298] p0004 879-30269  
Fabrication of structural elements p0025 879-30304  
ROCKWELL INTERNATIONAL CORP., PITTSBURG, PA.  
Erectable platform for science and applications  
payloads circa 1985 p0005 879-38749  
[AIAA 79-0931] p0005 879-38749

## S

SOLARTE CORP., ROCKVILLE, MD.  
An economic analysis of a commercial approach to  
the design and fabrication of a space power  
system p0036 879-34737  
[AIAA 79-0914] p0036 879-34737  
SPAR AEROSPACE PRODUCTS LTD., TORONTO (ONTARIO).  
Canadian development of large deployable solar  
arrays for communications spacecraft p0050 879-30754  
SPIRE CORP., BEDFORD, MASS.  
A combined spacecraft charging and pulsed X-ray  
simulation facility p0050 879-24054  
SYNICAL CORP., SUNNYVALE, CALIF.  
Solar thermo electric power generation for  
Mercury orbiter missions p0029 879-34738  
[AIAA 79-0915] p0029 879-34738

## T

TECHNISCHE UNIV., BERLIN (WEST GERMANY).  
MOSGEN: A potential European contribution in  
developing large solar generators suitable for  
growing power levels up to SPS-systems p0044 879-30752  
THERMO ELECTRON CORP., WALTHAM, MASS.  
Systems definition space-based power conversion  
systems p0041 879-23483  
[NASA-CN-150268] p0041 879-23483  
THOMSON-CSF, REEDON-LE-FORET (FRANCE).  
Feasibility study for a satellite frequency  
modulated radio communication system p0004 879-27176  
[ESA-CN-89-1151-FOL-1] p0004 879-27176  
TRW DEFENSE AND SPACE SYSTEMS GROUP, REDONDO BEACH,  
CALIF.  
Surface accuracy measurement system deployable  
reflector antennas p0013 879-34755  
[AIAA 79-0937] p0013 879-34755

## U

UNITED TECHNOLOGIES RESEARCH CENTER, FAIR HARTFORD,  
CONN.  
Graphite fiber reinforced glass matrix  
composites for aerospace applications p0023 879-41234

## V

VIRADY UNIV., BURLINGTON.  
New highly conducting coordination compounds p0040 879-22261  
[AD-A064735] p0040 879-22261  
VIRGINIA POLYTECHNIC INST. AND STATE UNIV.,  
BLACKSBURG.  
The dual-momenta control device for large space  
systems

[AIAA 79-0923] p0013 A79-34744  
Nonreflective boundary control of a vibrating  
string  
[AIAA 79-0950] p0013 A79-34761  
The dual momentum control device for large space  
systems - An example of distributed system  
adaptive control p0014 A79-411.6  
On adaptive modal control of large flexible  
spacecraft  
[AIAA 79-1779] p0016 A79-45406  
Indirect adaptive stabilization of a large,  
flexible, spinning spacecraft Simulation studies  
p0017 A79-50033  
Derivation of the equations of motion for  
complex structures by symbolic manipulation  
p0007 A79-52741

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### WASHINGTON UNIV., SEATTLE.

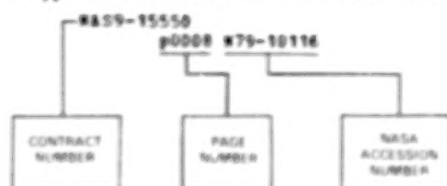
Solar-pumped lasers for space power transmission  
[AIAA PAPER 79-1011] p0017 A79-38202  
New energy conversion techniques in space,  
applicable to propulsion p0017 A79-40490  
[AIAA PAPER 79-1118]  
Computer modeling for a space power transmission  
system p0018 A79-51941

# CONTRACT NUMBER INDEX

TECHNOLOGY FOR LARGE SPACE SYSTEMS / A Special Bibliography (Suppl. 2)

JANUARY 1980

## Typical Contract Number Index Listing



Listings in this index are arranged alphabetically by contract number. Under each contract number, the accession numbers denoting documents that have been produced as a result of research done under that contract are arranged in ascending order with the NASA accession numbers appearing first. Preceding the accession number is the page number where the citation may be found.

NSG-1527  
p0013 A79-34763  
p0016 A79-45406  
p0017 A79-50033  
NSG-16-75-C-0756  
p0040 A79-22261  
506-17-13-20  
p0008 A79-33530  
526-71-03-01  
p0025 A79-80297  
953-36-00-00-72  
p0009 A79-22579

ASPA ORDER 3411  
p0024 A79-43321  
DASG60-77-C-0123  
p0013 A79-34763  
DFVLR-01-TD-047-AE/81/89T-20  
p0010 A79-53361  
DS-77-C-01-4024  
p0042 A79-23492  
p0042 A79-23496  
p0042 A79-23499  
p0042 A79-23500  
p0043 A79-23502  
p0044 A79-31251  
ESA-3206/77-P-RGT(SIC)  
p0004 A79-27376  
ESTEC-3396/77/RL-PP(SIC)  
p0012 A79-30564  
F04700-78-1-2539  
p0011 A79-23134  
F04701-76-C-0562  
p0024 A79-43306  
F04701-78-C-0039  
p0043 A79-28213  
F33615-77-C-5190  
p0024 A79-43321  
p0024 A79-43323  
JPL-954563  
p0044 A79-31764  
JPL-955081  
p0018 A79-27655  
NASA TASK 28  
p0408 A79-34761  
NASG-15581  
p0027 A79-53421  
NAS1-12346  
p0408 A79-34761  
NAS1-14346  
p0023 A79-43294  
NAS1-14887  
p0009 A79-34745  
NAS1-15183  
p0025 A79-30304  
NAS1-15469  
p0023 A79-43305  
NAS1-15520  
p0013 A79-34755  
NAS1-15548  
p0013 A79-34743  
NAS1-15642  
p0004 A79-23126  
NAS1-15644  
p0011 A79-24066  
NAS3-21134  
p0037 A79-38202  
NAS5-25091  
p0003 A79-53406  
NAS7-100  
p0029 A79-34718  
p0029 A79-34735  
p0029 A79-34738  
p0009 A79-34750  
p0013 A79-34752  
p0001 A79-34762  
p0027 A79-34982  
p0015 A79-45382  
p0018 A79-22177

p0028 A79-28201  
p0045 A79-32643  
NASG-31308  
p0040 A79-22617  
p0040 A79-22618  
p0040 A79-22619  
p0040 A79-22620  
NASG-31352  
p0030 A79-51094  
NASG-31626  
p0040 A79-22616  
p0041 A79-23483  
NASG-31847  
p0033 A79-38053  
NASG-32281  
p0011 A79-53404  
NASG-32394  
p0002 A79-53357  
NASG-32472  
p0011 A79-29213  
p0011 A79-29214  
NASG-32475  
p0041 A79-22632  
p0041 A79-22633  
p0041 A79-22634  
p0041 A79-23484  
p0041 A79-23485  
p0042 A79-23486  
p0042 A79-23487  
p0042 A79-23488  
p0042 A79-23489  
NASG-22637  
p0008 A79-22178  
NASG-32660  
p0016 A79-29215  
NASG-14782  
p0049 A79-23666  
NASG-14916  
p0002 A79-53357  
NASG-15156  
p0038 A79-51941  
p0040 A79-30750  
NASG-15310  
p0002 A79-53357  
p0011 A79-29203  
NASG-15634  
p0038 A79-51941  
NASG-15718  
p0004 A79-30264  
p0050 A79-30267  
p0004 A79-30268  
p0004 A79-30269  
NSG-48-002-004  
p0037 A79-40490  
NSC A-2181  
p0008 A79-53346  
NSRRC-A-4183  
p0018 A79-53945  
NSG-1114  
p0007 A79-52741  
NSG-1185  
p0008 A79-23128  
NSG-1414  
p0016 A79-47236  
p0018 A79-25122

# REPORT/ACCESSION NUMBER INDEX

TECHNOLOGY FOR LARGE SPACE SYSTEMS / A Special Bibliography (Suppl. 2)

JANUARY 1980

## Typical Report / Accession Number Listing



Listings in this index are arranged alphabetically by report number. The page number indicates the page on which the citation may be located. The accession number denotes the number by which the citation is identified. An asterisk (\*) indicates that the item is a NASA report. A pound sign (#) indicates that the item is available on microfiche.

NAS 79-1000 ..... P0001 79-1000#  
 NAS 79-1001 ..... P0002 79-1001#  
 NAS 79-1002 ..... P0003 79-1002#  
 NAS 79-1003 ..... P0004 79-1003#  
 NAS 79-1004 ..... P0005 79-1004#  
 NAS 79-1005 ..... P0006 79-1005#  
 NAS 79-1006 ..... P0007 79-1006#  
 NAS 79-1007 ..... P0008 79-1007#  
 NAS 79-1008 ..... P0009 79-1008#  
 NAS 79-1009 ..... P0010 79-1009#  
 NAS 79-1010 ..... P0011 79-1010#  
 NAS 79-1011 ..... P0012 79-1011#  
 NAS 79-1012 ..... P0013 79-1012#  
 NAS 79-1013 ..... P0014 79-1013#  
 NAS 79-1014 ..... P0015 79-1014#  
 NAS 79-1015 ..... P0016 79-1015#  
 NAS 79-1016 ..... P0017 79-1016#  
 NAS 79-1017 ..... P0018 79-1017#  
 NAS 79-1018 ..... P0019 79-1018#  
 NAS 79-1019 ..... P0020 79-1019#  
 NAS 79-1020 ..... P0021 79-1020#  
 NAS 79-1021 ..... P0022 79-1021#  
 NAS 79-1022 ..... P0023 79-1022#  
 NAS 79-1023 ..... P0024 79-1023#  
 NAS 79-1024 ..... P0025 79-1024#  
 NAS 79-1025 ..... P0026 79-1025#  
 NAS 79-1026 ..... P0027 79-1026#  
 NAS 79-1027 ..... P0028 79-1027#  
 NAS 79-1028 ..... P0029 79-1028#  
 NAS 79-1029 ..... P0030 79-1029#  
 NAS 79-1030 ..... P0031 79-1030#  
 NAS 79-1031 ..... P0032 79-1031#  
 NAS 79-1032 ..... P0033 79-1032#  
 NAS 79-1033 ..... P0034 79-1033#  
 NAS 79-1034 ..... P0035 79-1034#  
 NAS 79-1035 ..... P0036 79-1035#  
 NAS 79-1036 ..... P0037 79-1036#  
 NAS 79-1037 ..... P0038 79-1037#  
 NAS 79-1038 ..... P0039 79-1038#  
 NAS 79-1039 ..... P0040 79-1039#  
 NAS 79-1040 ..... P0041 79-1040#  
 NAS 79-1041 ..... P0042 79-1041#  
 NAS 79-1042 ..... P0043 79-1042#  
 NAS 79-1043 ..... P0044 79-1043#  
 NAS 79-1044 ..... P0045 79-1044#  
 NAS 79-1045 ..... P0046 79-1045#  
 NAS 79-1046 ..... P0047 79-1046#  
 NAS 79-1047 ..... P0048 79-1047#  
 NAS 79-1048 ..... P0049 79-1048#  
 NAS 79-1049 ..... P0050 79-1049#  
 NAS 79-1050 ..... P0051 79-1050#  
 NAS 79-1051 ..... P0052 79-1051#  
 NAS 79-1052 ..... P0053 79-1052#  
 NAS 79-1053 ..... P0054 79-1053#  
 NAS 79-1054 ..... P0055 79-1054#  
 NAS 79-1055 ..... P0056 79-1055#  
 NAS 79-1056 ..... P0057 79-1056#  
 NAS 79-1057 ..... P0058 79-1057#  
 NAS 79-1058 ..... P0059 79-1058#  
 NAS 79-1059 ..... P0060 79-1059#  
 NAS 79-1060 ..... P0061 79-1060#  
 NAS 79-1061 ..... P0062 79-1061#  
 NAS 79-1062 ..... P0063 79-1062#  
 NAS 79-1063 ..... P0064 79-1063#  
 NAS 79-1064 ..... P0065 79-1064#  
 NAS 79-1065 ..... P0066 79-1065#  
 NAS 79-1066 ..... P0067 79-1066#  
 NAS 79-1067 ..... P0068 79-1067#  
 NAS 79-1068 ..... P0069 79-1068#  
 NAS 79-1069 ..... P0070 79-1069#  
 NAS 79-1070 ..... P0071 79-1070#  
 NAS 79-1071 ..... P0072 79-1071#  
 NAS 79-1072 ..... P0073 79-1072#  
 NAS 79-1073 ..... P0074 79-1073#  
 NAS 79-1074 ..... P0075 79-1074#  
 NAS 79-1075 ..... P0076 79-1075#  
 NAS 79-1076 ..... P0077 79-1076#  
 NAS 79-1077 ..... P0078 79-1077#  
 NAS 79-1078 ..... P0079 79-1078#  
 NAS 79-1079 ..... P0080 79-1079#  
 NAS 79-1080 ..... P0081 79-1080#  
 NAS 79-1081 ..... P0082 79-1081#  
 NAS 79-1082 ..... P0083 79-1082#  
 NAS 79-1083 ..... P0084 79-1083#  
 NAS 79-1084 ..... P0085 79-1084#  
 NAS 79-1085 ..... P0086 79-1085#  
 NAS 79-1086 ..... P0087 79-1086#  
 NAS 79-1087 ..... P0088 79-1087#  
 NAS 79-1088 ..... P0089 79-1088#  
 NAS 79-1089 ..... P0090 79-1089#  
 NAS 79-1090 ..... P0091 79-1090#  
 NAS 79-1091 ..... P0092 79-1091#  
 NAS 79-1092 ..... P0093 79-1092#  
 NAS 79-1093 ..... P0094 79-1093#  
 NAS 79-1094 ..... P0095 79-1094#  
 NAS 79-1095 ..... P0096 79-1095#  
 NAS 79-1096 ..... P0097 79-1096#  
 NAS 79-1097 ..... P0098 79-1097#  
 NAS 79-1098 ..... P0099 79-1098#  
 NAS 79-1099 ..... P0100 79-1099#  
 NAS 79-1100 ..... P0101 79-1100#  
 NAS 79-1101 ..... P0102 79-1101#  
 NAS 79-1102 ..... P0103 79-1102#  
 NAS 79-1103 ..... P0104 79-1103#  
 NAS 79-1104 ..... P0105 79-1104#  
 NAS 79-1105 ..... P0106 79-1105#  
 NAS 79-1106 ..... P0107 79-1106#  
 NAS 79-1107 ..... P0108 79-1107#  
 NAS 79-1108 ..... P0109 79-1108#  
 NAS 79-1109 ..... P0110 79-1109#  
 NAS 79-1110 ..... P0111 79-1110#  
 NAS 79-1111 ..... P0112 79-1111#  
 NAS 79-1112 ..... P0113 79-1112#  
 NAS 79-1113 ..... P0114 79-1113#  
 NAS 79-1114 ..... P0115 79-1114#  
 NAS 79-1115 ..... P0116 79-1115#  
 NAS 79-1116 ..... P0117 79-1116#  
 NAS 79-1117 ..... P0118 79-1117#  
 NAS 79-1118 ..... P0119 79-1118#  
 NAS 79-1119 ..... P0120 79-1119#  
 NAS 79-1120 ..... P0121 79-1120#  
 NAS 79-1121 ..... P0122 79-1121#  
 NAS 79-1122 ..... P0123 79-1122#  
 NAS 79-1123 ..... P0124 79-1123#  
 NAS 79-1124 ..... P0125 79-1124#  
 NAS 79-1125 ..... P0126 79-1125#  
 NAS 79-1126 ..... P0127 79-1126#  
 NAS 79-1127 ..... P0128 79-1127#  
 NAS 79-1128 ..... P0129 79-1128#  
 NAS 79-1129 ..... P0130 79-1129#  
 NAS 79-1130 ..... P0131 79-1130#  
 NAS 79-1131 ..... P0132 79-1131#  
 NAS 79-1132 ..... P0133 79-1132#  
 NAS 79-1133 ..... P0134 79-1133#  
 NAS 79-1134 ..... P0135 79-1134#  
 NAS 79-1135 ..... P0136 79-1135#  
 NAS 79-1136 ..... P0137 79-1136#  
 NAS 79-1137 ..... P0138 79-1137#  
 NAS 79-1138 ..... P0139 79-1138#  
 NAS 79-1139 ..... P0140 79-1139#  
 NAS 79-1140 ..... P0141 79-1140#  
 NAS 79-1141 ..... P0142 79-1141#  
 NAS 79-1142 ..... P0143 79-1142#  
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 NAS 79-1144 ..... P0145 79-1144#  
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 NAS 79-1146 ..... P0147 79-1146#  
 NAS 79-1147 ..... P0148 79-1147#  
 NAS 79-1148 ..... P0149 79-1148#  
 NAS 79-1149 ..... P0150 79-1149#  
 NAS 79-1150 ..... P0151 79-1150#  
 NAS 79-1151 ..... P0152 79-1151#  
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 NAS 79-1154 ..... P0155 79-1154#  
 NAS 79-1155 ..... P0156 79-1155#  
 NAS 79-1156 ..... P0157 79-1156#  
 NAS 79-1157 ..... P0158 79-1157#  
 NAS 79-1158 ..... P0159 79-1158#  
 NAS 79-1159 ..... P0160 79-1159#  
 NAS 79-1160 ..... P0161 79-1160#  
 NAS 79-1161 ..... P0162 79-1161#  
 NAS 79-1162 ..... P0163 79-1162#  
 NAS 79-1163 ..... P0164 79-1163#  
 NAS 79-1164 ..... P0165 79-1164#  
 NAS 79-1165 ..... P0166 79-1165#  
 NAS 79-1166 ..... P0167 79-1166#  
 NAS 79-1167 ..... P0168 79-1167#  
 NAS 79-1168 ..... P0169 79-1168#  
 NAS 79-1169 ..... P0170 79-1169#  
 NAS 79-1170 ..... P0171 79-1170#  
 NAS 79-1171 ..... P0172 79-1171#  
 NAS 79-1172 ..... P0173 79-1172#  
 NAS 79-1173 ..... P0174 79-1173#  
 NAS 79-1174 ..... P0175 79-1174#  
 NAS 79-1175 ..... P0176 79-1175#  
 NAS 79-1176 ..... P0177 79-1176#  
 NAS 79-1177 ..... P0178 79-1177#  
 NAS 79-1178 ..... P0179 79-1178#  
 NAS 79-1179 ..... P0180 79-1179#  
 NAS 79-1180 ..... P0181 79-1180#  
 NAS 79-1181 ..... P0182 79-1181#  
 NAS 79-1182 ..... P0183 79-1182#  
 NAS 79-1183 ..... P0184 79-1183#  
 NAS 79-1184 ..... P0185 79-1184#  
 NAS 79-1185 ..... P0186 79-1185#  
 NAS 79-1186 ..... P0187 79-1186#  
 NAS 79-1187 ..... P0188 79-1187#  
 NAS 79-1188 ..... P0189 79-1188#  
 NAS 79-1189 ..... P0190 79-1189#  
 NAS 79-1190 ..... P0191 79-1190#  
 NAS 79-1191 ..... P0192 79-1191#  
 NAS 79-1192 ..... P0193 79-1192#  
 NAS 79-1193 ..... P0194 79-1193#  
 NAS 79-1194 ..... P0195 79-1194#  
 NAS 79-1195 ..... P0196 79-1195#  
 NAS 79-1196 ..... P0197 79-1196#  
 NAS 79-1197 ..... P0198 79-1197#  
 NAS 79-1198 ..... P0199 79-1198#  
 NAS 79-1199 ..... P0200 79-1199#  
 NAS 79-1200 ..... P0201 79-1200#  
 NAS 79-1201 ..... P0202 79-1201#  
 NAS 79-1202 ..... P0203 79-1202#  
 NAS 79-1203 ..... P0204 79-1203#  
 NAS 79-1204 ..... P0205 79-1204#  
 NAS 79-1205 ..... P0206 79-1205#  
 NAS 79-1206 ..... P0207 79-1206#  
 NAS 79-1207 ..... P0208 79-1207#  
 NAS 79-1208 ..... P0209 79-1208#  
 NAS 79-1209 ..... P0210 79-1209#  
 NAS 79-1210 ..... P0211 79-1210#  
 NAS 79-1211 ..... P0212 79-1211#  
 NAS 79-1212 ..... P0213 79-1212#  
 NAS 79-1213 ..... P0214 79-1213#  
 NAS 79-1214 ..... P0215 79-1214#  
 NAS 79-1215 ..... P0216 79-1215#  
 NAS 79-1216 ..... P0217 79-1216#  
 NAS 79-1217 ..... P0218 79-1217#  
 NAS 79-1218 ..... P0219 79-1218#  
 NAS 79-1219 ..... P0220 79-1219#  
 NAS 79-1220 ..... P0221 79-1220#  
 NAS 79-1221 ..... P0222 79-1221#  
 NAS 79-1222 ..... P0223 79-1222#  
 NAS 79-1223 ..... P0224 79-1223#  
 NAS 79-1224 ..... P0225 79-1224#  
 NAS 79-1225 ..... P0226 79-1225#  
 NAS 79-1226 ..... P0227 79-1226#  
 NAS 79-1227 ..... P0228 79-1227#  
 NAS 79-1228 ..... P0229 79-1228#  
 NAS 79-1229 ..... P0230 79-1229#  
 NAS 79-1230 ..... P0231 79-1230#  
 NAS 79-1231 ..... P0232 79-1231#  
 NAS 79-1232 ..... P0233 79-1232#  
 NAS 79-1233 ..... P0234 79-1233#  
 NAS 79-1234 ..... P0235 79-1234#  
 NAS 79-1235 ..... P0236 79-1235#  
 NAS 79-1236 ..... P0237 79-1236#  
 NAS 79-1237 ..... P0238 79-1237#  
 NAS 79-1238 ..... P0239 79-1238#  
 NAS 79-1239 ..... P0240 79-1239#  
 NAS 79-1240 ..... P0241 79-1240#  
 NAS 79-1241 ..... P0242 79-1241#  
 NAS 79-1242 ..... P0243 79-1242#  
 NAS 79-1243 ..... P0244 79-1243#  
 NAS 79-1244 ..... P0245 79-1244#  
 NAS 79-1245 ..... P0246 79-1245#  
 NAS 79-1246 ..... P0247 79-1246#  
 NAS 79-1247 ..... P0248 79-1247#  
 NAS 79-1248 ..... P0249 79-1248#  
 NAS 79-1249 ..... P0250 79-1249#  
 NAS 79-1250 ..... P0251 79-1250#  
 NAS 79-1251 ..... P0252 79-1251#  
 NAS 79-1252 ..... P0253 79-1252#  
 NAS 79-1253 ..... P0254 79-1253#  
 NAS 79-1254 ..... P0255 79-1254#  
 NAS 79-1255 ..... P0256 79-1255#  
 NAS 79-1256 ..... P0257 79-1256#  
 NAS 79-1257 ..... P0258 79-1257#  
 NAS 79-1258 ..... P0259 79-1258#  
 NAS 79-1259 ..... P0260 79-1259#  
 NAS 79-1260 ..... P0261 79-1260#  
 NAS 79-1261 ..... P0262 79-1261#  
 NAS 79-1262 ..... P0263 79-1262#  
 NAS 79-1263 ..... P0264 79-1263#  
 NAS 79-1264 ..... P0265 79-1264#  
 NAS 79-1265 ..... P0266 79-1265#  
 NAS 79-1266 ..... P0267 79-1266#  
 NAS 79-1267 ..... P0268 79-1267#  
 NAS 79-1268 ..... P0269 79-1268#  
 NAS 79-1269 ..... P0270 79-1269#  
 NAS 79-1270 ..... P0271 79-1270#  
 NAS 79-1271 ..... P0272 79-1271#  
 NAS 79-1272 ..... P0273 79-1272#  
 NAS 79-1273 ..... P0274 79-1273#  
 NAS 79-1274 ..... P0275 79-1274#  
 NAS 79-1275 ..... P0276 79-1275#  
 NAS 79-1276 ..... P0277 79-1276#  
 NAS 79-1277 ..... P0278 79-1277#  
 NAS 79-1278 ..... P0279 79-1278#  
 NAS 79-1279 ..... P0280 79-1279#  
 NAS 79-1280 ..... P0281 79-1280#  
 NAS 79-1281 ..... P0282 79-1281#  
 NAS 79-1282 ..... P0283 79-1282#  
 NAS 79-1283 ..... P0284 79-1283#  
 NAS 79-1284 ..... P0285 79-1284#  
 NAS 79-1285 ..... P0286 79-1285#  
 NAS 79-1286 ..... P0287 79-1286#  
 NAS 79-1287 ..... P0288 79-1287#  
 NAS 79-1288 ..... P0289 79-1288#  
 NAS 79-1289 ..... P0290 79-1289#  
 NAS 79-1290 ..... P0291 79-1290#  
 NAS 79-1291 ..... P0292 79-1291#  
 NAS 79-1292 ..... P0293 79-1292#  
 NAS 79-1293 ..... P0294 79-1293#  
 NAS 79-1294 ..... P0295 79-1294#  
 NAS 79-1295 ..... P0296 79-1295#  
 NAS 79-1296 ..... P0297 79-1296#  
 NAS 79-1297 ..... P0298 79-1297#  
 NAS 79-1298 ..... P0299 79-1298#  
 NAS 79-1299 ..... P0300 79-1299#  
 NAS 79-1300 ..... P0301 79-1300#  
 NAS 79-1301 ..... P0302 79-1301#  
 NAS 79-1302 ..... P0303 79-1302#  
 NAS 79-1303 ..... P0304 79-1303#  
 NAS 79-1304 ..... P0305 79-1304#  
 NAS 79-1305 ..... P0306 79-1305#  
 NAS 79-1306 ..... P0307 79-1306#  
 NAS 79-1307 ..... P0308 79-1307#  
 NAS 79-1308 ..... P0309 79-1308#  
 NAS 79-1309 ..... P0310 79-1309#  
 NAS 79-1310 ..... P0311 79-1310#  
 NAS 79-1311 ..... P0312 79-1311#  
 NAS 79-1312 ..... P0313 79-1312#  
 NAS 79-1313 ..... P0314 79-1313#  
 NAS 79-1314 ..... P0315 79-1314#  
 NAS 79-1315 ..... P0316 79-1315#  
 NAS 79-1316 ..... P0317 79-1316#  
 NAS 79-1317 ..... P0318 79-1317#  
 NAS 79-1318 ..... P0319 79-1318#  
 NAS 79-1319 ..... P0320 79-1319#  
 NAS 79-1320 ..... P0321 79-1320#  
 NAS 79-1321 ..... P0322 79-1321#  
 NAS 79-1322 ..... P0323 79-1322#  
 NAS 79-1323 ..... P0324 79-1323#  
 NAS 79-1324 ..... P0325 79-1324#  
 NAS 79-1325 ..... P0326 79-1325#  
 NAS 79-1326 ..... P0327 79-1326#  
 NAS 79-1327 ..... P0328 79-1327#  
 NAS 79-1328 ..... P0329 79-1328#  
 NAS 79-1329 ..... P0330 79-1329#  
 NAS 79-1330 ..... P0331 79-1330#  
 NAS 79-1331 ..... P0332 79-1331#  
 NAS 79-1332 ..... P0333 79-1332#  
 NAS 79-1333 ..... P0334 79-1333#  
 NAS 79-1334 ..... P0335 79-1334#  
 NAS 79-1335 ..... P0336 79-1335#  
 NAS 79-1336 ..... P0337 79-1336#  
 NAS 79-1337 ..... P0338 79-1337#  
 NAS 79-1338 ..... P0339 79-1338#  
 NAS 79-1339 ..... P0340 79-1339#  
 NAS 79-1340 ..... P0341 79-1340#  
 NAS 79-1341 ..... P0342 79-1341#  
 NAS 79-1342 ..... P0343 79-1342#  
 NAS 79-1343 ..... P0344 79-1343#  
 NAS 79-1344 ..... P0345 79-1344#  
 NAS 79-1345 ..... P0346 79-1345#  
 NAS 79-1346 ..... P0347 79-1346#  
 NAS 79-1347 ..... P0348 79-1347#  
 NAS 79-1348 ..... P0349 79-1348#  
 NAS 79-1349 ..... P0350 79-1349#  
 NAS 79-1350 ..... P0351 79-1350#  
 NAS 79-1351 ..... P0352 79-1351#  
 NAS 79-1352 ..... P0353 79-1352#  
 NAS 79-1353 ..... P0354 79-1353#  
 NAS 79-1354 ..... P0355 79-1354#  
 NAS 79-1355 ..... P0356 79-1355#  
 NAS 79-1356 ..... P0357 79-1356#  
 NAS 79-1357 ..... P0358 79-1357#  
 NAS 79-1358 ..... P0359 79-1358#  
 NAS 79-1359 ..... P0360 79-1359#  
 NAS 79-1360 ..... P0361 79-1360#  
 NAS 79-1361 ..... P0362 79-1361#  
 NAS 79-1362 ..... P0363 79-1362#  
 NAS 79-1363 ..... P0364 79-1363#  
 NAS 79-1364 ..... P0365 79-1364#  
 NAS 79-1365 ..... P0366 79-1365#  
 NAS 79-1366 ..... P0367 79-1366#  
 NAS 79-1367 ..... P0368 79-1367#  
 NAS 79-1368 ..... P0369 79-1368#  
 NAS 79-1369 ..... P0370 79-1369#  
 NAS 79-1370 ..... P0371 79-1370#  
 NAS 79-1371 ..... P0372 79-1371#  
 NAS 79-1372 ..... P0373 79-1372#  
 NAS 79-1373 ..... P0374 79-1373#  
 NAS 79-1374 ..... P0375 79-1374#  
 NAS 79-1375 ..... P0376 79-1375#  
 NAS 79-1376 ..... P0377 79-1376#  
 NAS 79-1377 ..... P0378 79-1377#  
 NAS 79-1378 ..... P0379 79-1378#  
 NAS 79-1379 ..... P0380 79-1379#  
 NAS 79-1380 ..... P0381 79-1380#  
 NAS 79-1381 ..... P0382 79-1381#  
 NAS 79-1382 ..... P0383 79-1382#  
 NAS 79-1383 ..... P0384 79-1383#  
 NAS 79-1384 ..... P0385 79-1384#  
 NAS 79-1385 ..... P0386 79-1385#  
 NAS 79-1386 ..... P0387 79-1386#  
 NAS 79-1387 ..... P0388 79-1387#  
 NAS 79-1388 ..... P0389 79-1388#  
 NAS 79-1389 ..... P0390 79-1389#  
 NAS 79-1390 ..... P0391 79-1390#  
 NAS 79-1391 ..... P0392 79-1391#  
 NAS 79-1392 ..... P0393 79-1392#  
 NAS 79-1393 ..... P0394 79-1393#  
 NAS 79-1394 ..... P0395 79-1394#  
 NAS 79-1395 ..... P0396 79-1395#  
 NAS 79-1396 ..... P0397 79-1396#  
 NAS 79-1397 ..... P0398 79-1397#  
 NAS 79-1398 ..... P0399 79-1398#  
 NAS 79-1399 ..... P0400 79-1399#  
 NAS 79-1400 ..... P0401 79-1400#  
 NAS 79-1401 ..... P0402 79-1401#  
 NAS 79-1402 ..... P0403 79-1402#  
 NAS 79-1403 ..... P0404 79-1403#  
 NAS 79-1404 ..... P0405 79-1404#  
 NAS 79-1405 ..... P0406 79-1405#  
 NAS 79-1406 ..... P04

IAF PAPER 75-173 ..... p0039 879-53334  
 IAF PAPER 75-174 ..... p0039 879-53335  
 IAF PAPER 75-176 ..... p0039 879-53336  
 IAF PAPER 75-177 ..... p0039 879-53337  
 IAF PAPER 75-182 ..... p0040 879-53346  
 IAF PAPER 75-204 ..... p0040 879-53354  
 IAF PAPER 75-207 ..... p0042 879-53357  
 IAF PAPER 75-208 ..... p0042 879-53358  
 IAF PAPER 75-209 ..... p0039 879-53359  
 IAF PAPER 75-210 ..... p0040 879-53360  
 IAF PAPER 75-211 ..... p0040 879-53361  
 IAF PAPER 75-212 ..... p0040 879-53362  
 IAF PAPER 75-210 ..... p0041 879-53404  
 IAF PAPER 75-211 ..... p0043 879-53405  
 IAF PAPER 75-212 ..... p0043 879-53406  
 IAF PAPER 75-217 ..... p0043 879-53409

JPL-808-79-23 ..... p0048 879-22177\*  
 JPL-808-79-62 ..... p0028 879-22201\*

JPL-79-0-104 ..... p0048 879-22155\*

L-1281 ..... p0008 879-11500\*  
 L-12951 ..... p0025 879-10247\*

NASA-CASE-LAB-12077-1 ..... p0044 879-21425\*

NASA-CF-2071 ..... p0050 879-24001\*  
 NASA-CF-2079 ..... p0025 879-10247\*  
 NASA-CF-2081 ..... p0049 879-22539\*

NASA-CR-150269 ..... p0040 879-22616\*  
 NASA-CR-150268 ..... p0041 879-22617\*  
 NASA-CR-150294 ..... p0040 879-22617\*  
 NASA-CR-150295 ..... p0040 879-22618\*  
 NASA-CR-150296 ..... p0040 879-22619\*  
 NASA-CR-150297 ..... p0040 879-22620\*  
 NASA-CR-157432 ..... p0042 879-22696\*  
 NASA-CR-157435 ..... p0042 879-22699\*  
 NASA-CR-157436 ..... p0042 879-22700\*  
 NASA-CR-157438 ..... p0043 879-22702\*  
 NASA-CR-158509 ..... p0008 879-22129\*  
 NASA-CR-158513 ..... p0048 879-22177\*  
 NASA-CR-158600 ..... p0042 879-22692\*  
 NASA-CR-158690 ..... p0048 879-22720\*  
 NASA-CR-158729 ..... p0049 879-22654\*  
 NASA-CR-158810 ..... p0028 879-22601\*  
 NASA-CR-159040 ..... p0004 879-22126\*  
 NASA-CR-159040 ..... p0041 879-22666\*  
 NASA-CR-160160 ..... p0049 879-22666\*  
 NASA-CR-160208 ..... p0041 879-22620\*  
 NASA-CR-160295 ..... p0004 879-10266\*  
 NASA-CR-160296 ..... p0050 879-10267\*  
 NASA-CR-160297 ..... p0004 879-10268\*  
 NASA-CR-160298 ..... p0004 879-10269\*  
 NASA-CR-161214 ..... p0041 879-22612\*  
 NASA-CR-161215 ..... p0041 879-22633\*  
 NASA-CR-161216 ..... p0041 879-22634\*  
 NASA-CR-161217 ..... p0008 879-22178\*  
 NASA-CR-161218 ..... p0041 879-22644\*  
 NASA-CR-161219 ..... p0041 879-22645\*  
 NASA-CR-161220 ..... p0042 879-22646\*  
 NASA-CR-161221 ..... p0042 879-22647\*  
 NASA-CR-161222 ..... p0042 879-22648\*  
 NASA-CR-161223 ..... p0042 879-22649\*  
 NASA-CR-161206 ..... p0041 879-22613\*  
 NASA-CR-161207 ..... p0041 879-22614\*  
 NASA-CR-161208 ..... p0041 879-22615\*  
 NASA-CR-162279 ..... p0044 879-11764\*  
 NASA-CR-162310 ..... p0044 879-11251\*

NASA-TM-78215 ..... p0024 879-24441\*  
 NASA-TM-79125 ..... p0004 879-22191\*  
 NASA-TM-79141 ..... p0030 879-22190\*  
 NASA-TM-79153 ..... p0040 879-22193\*  
 NASA-TM-79154 ..... p0049 879-22180\*  
 NASA-TM-79190 ..... p0031 879-25129\*  
 NASA-TM-80280 ..... p0003 879-32174\*  
 NASA-TM-80355 ..... p0042 879-24435\*

NASA-TF-1522 ..... p0008 879-11500\*

NSS-SPSS-SP013 ..... p0041 879-29213\*  
 NSS-SPSS-SP013 ..... p0041 879-29214\*

PROL-95-146 ..... p0040 879-10726

QTP-1 ..... p0041 879-24366\*

REF-77-145-1-001-1 ..... p0040 879-22617\*  
 REF-75-36 ..... p0040 879-22539\*

9-096 ..... p0049 879-22539\*

SASD-79-79-3 ..... p0041 879-22134\*  
 SASD-79-79-64 ..... p0041 879-22135\*

SE-4024-21 ..... p0040 879-11251\*

SP-140 ..... p0040 879-10730\*

SSD-79-0010-1-001-1 ..... p0041 879-22640\*  
 SSD-79-0010-2-1-001-2-001-1 ..... p0041 879-22641\*  
 SSD-79-0010-2-2-001-2-001-2 ..... p0042 879-22642\*  
 SSD-79-0010-2-2-001-2-001-2-001 ..... p0042 879-22643\*  
 SSD-79-0010-3 ..... p0041 879-22644\*  
 SSD-79-0010-4-001-4 ..... p0042 879-22645\*  
 SSD-79-0010-5 ..... p0041 879-22646\*  
 SSD-79-0010-6 ..... p0041 879-22647\*  
 SSD-79-0010-7-001-7 ..... p0042 879-22648\*  
 SSD-79-0123 ..... p0004 879-10248\*  
 SSD-79-0124 ..... p0004 879-10249\*  
 SSD-79-0126 ..... p0004 879-10250\*

TE-11 ..... p0040 879-22261\*

TR-0079(4960-04)-1 ..... p0041 879-22134\*  
 TR-0079(4960-04)-5 ..... p0041 879-22135\*

TR-0079(4960-04)-5 ..... p0041 879-22135\*

TR-0079(4960-04)-5 ..... p0041 879-22135\*

TR-0079(4960-04)-5 ..... p0041 879-22135\*

TR-0079(4960-04)-5 ..... p0041 879-22135\*

TR-0079(4960-04)-5 ..... p0041 879-22135\*

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TR-0079(4960-04)-5 ..... p0041 879-22135\*

TR-0079(4960-04)-5 ..... p0041 879-22135\*

TR-0079(4960-04)-5 ..... p0041 879-22135\*



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